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ENGAGING ENGINEERING EDUCATION

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SEFI 2020

48TH ANNUAL CONFERENCE

SEFI — EUROPEAN SOCIETY FOR ENGINEERING EDUCATION

SEFI is the largest network of higher engineering education institutions (HEIs) and educators in Europe. Created in 1973, SEFI is an international non-profit organisation aiming to support, promote and improve European higher engineering education, enhancing the status of both engineering education and engineering in society.

SEFI is an international forum composed of higher engineering education institutions, academic staff and teachers, students, related associations and companies present in 48 countries. Through its membership and network, SEFI reaches approximately 160000 academics and 1000000 students. SEFI represents more than 4 decades of passion, dedication and high expertise in engineering education through actions undertaken according to its values: engagement and responsibility, respect of diversity and different cultures, institutional inclusiveness, multidisciplinary and openness, transparency, sustainability, creativity and professionalism. SEFI formulates ideas and positions on engineering education issues, influences engineering education in Europe, acts as a link between its members and European and worldwide bodies, contributes to the recruitment of good students whilst always promoting an international dimension in engineering curricula.

Our activities: Annual scientific conferences, annual conventions for engineering deans, ad hoc seminars/workshops organised by our working groups and special committees, scientific publications (incl. the bi-monthly European Journal of Engineering Education), European projects under ERASMUS + and Horizon2020, position papers, European debates, cooperation with other major European and international bodies. The cooperation with partner and sister engineering organisations in Europe and in the world is also one of our priorities.

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SEFI
ANNUAL CONFERENCE
20-24 September 2020
ENSCHEDE | THE NETHERLANDS

ENGAGING ENGINEERING EDUCATION

Engineering students engage with society designing new solutions to help solve complex problems. Interdisciplinary opportunities arise when they engage with other disciplines. Engagement of businesses and organisations helps to prepare our students for their future career. The 48th SEFI Annual Conference focuses on engaging current and future students in their education and in an engineering career by bringing together teachers, researchers, engineering professionals, students, managers, policymakers and deans in higher education. Via research papers, concept papers, short papers and workshops, participants have contributed on the following topics, between brackets the number of submissions that link to each topic[1]:

- Interdisciplinary engineering education, linking different disciplines both inside and outside engineering, linking with society (50).
- Engineering curriculum design, challenge based education, maker projects, use of professional tools (33).
- Sustainability and ethics, embedded and dedicated approaches (25).
- Mathematics in the engineering curriculum (10).
- Physics in the engineering curriculum (10).
- Higher education and business: collaborations and career support (12).
- Diversity and inclusiveness (22).
- Internationalisation, exchange options, joint programs (5).
- Future engineering skills and talent management (48).
- E-learning, open and online learning, blended learning, virtual reality (34).
- Engineering in Schools, improving visibility of engineering disciplines (12).
- Niche & novel engineering education topics (25).

Session formats were somewhat adjusted after it was decided to have an online conference. This way all sessions are optimized for both good introductions but also for questions and debate. A highly valued tradition is to kick off the conference on Sunday with a doctoral symposium in which engineering education phD candidates discuss their work with peers and senior engineering education researchers from around the world.

[1] Each contributed was asked to link to two topics allowing overlapping submissions to be visible in both.

WELCOME

JAN VAN DER VEEN
ELAN, Department of Teacher Development
University of Twente
SEFI2020 Chair

Welcome at the 48th SEFI Annual Conference! *Engaging Engineering Education* is what we are working on, even more so now that large parts of our education have moved online. We face many challenges, such as: improving inclusiveness of our programs, increasing sustainability in many areas, preparing our students with professional skills, developing new interdisciplinary engineering domains and contributing to the economy in a meaningful way. Let us now celebrate the progress reported and let us make plans for new engineering education activities. The keynotes and 150 contributions by academics and students will be inspiration for us all.

Together with SEFI, the University of Twente is hosting this conference working together with Saxion University of Applied Sciences and the Technical Universities of Delft, Eindhoven and Wageningen, our partners in the 4TU Centre for Engineering Education.
We thank all our international colleagues who invested considerable time and effort in preparing papers, sessions, workshops, symposia and those who contributed to this conference via the International Organizing Committee and via reviewing proposals.

We are proud and happy to host this first online SEFI annual conference. Engage with your colleagues, get your inspiration and debate how we can do even better. Finally, the community is used to enjoy and celebrate this yearly gathering. Let's make that happen online as well, with a special warm welcome to many newcomers.

KEYNOTE SPEAKERS

Keynote Speakers:

GREET LANGIE

Professor Greet Langie is since 2012 the vicedean of education of the Faculty of Engineering Technology at KU Leuven (Belgium). She's responsible for the design and implementation of a completely new engineering curriculum, that in the end will be organized for more than 6000 students. As a researcher in Engineering Education Research, she founded LESEC, the Leuven Engineering and Science Education Center. This KU Leuven-community gathers researchers and practitioners contributing to the advancement of STEM education. Her research interests are in the domain of study career guidance: the transition from secondary education to higher education and the transition from university to professional life.

Professor Langie received the IGIP title 'ING.PAED.IGIP h.c.'. She is active in several international networks such as: board member of SEFI, co-organizer of the IIDEA-summercourse at Tsinghua University and member of the BEST Advisory Board.

FOCUS ON THE EXIT TO KEEP THEM IN. CAREER DEVELOPMENT AT THE START OF ENGINEERING EDUCATION

The world of work after the Covid-19 battle will look different. Career development will become even more important. Research has shown that a better understanding of the professional future has positive outcomes for student learning and job satisfaction. Knowing what an engineer is and what kind of engineer students want to be, requires the ability to critically reflect on personal interests and strengths and weaknesses. How can we support our students to become more aware of their engineering identity and the wide variety of career options?

PIERRE DILLENBOURG

Pierre Dillenbourg is a full professor at the educational ergonomy lab of EPFL (Lausanne, Switzerland). His projects combine the design, building, testing and researching of new learning technologies and online learning. Research areas include virtual reality, MOOCs , ergonomy, educational robotics and learning analytics. This has resulted in cutting-edge applications with European partners, as well as numerous master and phd theses. Pierre Dillenbourg heads the EdTech Collider incubator for new educational technology spin-offs.

ESCAPING REALITY: THE VALUE OF 'A' IN AUGMENTED REALITY

Virtual reality and augmented reality strive for realism. In virtual reality, the holy grail is to create photorealistic scenes in order to generate a true feeling of immersion. In augmented reality, developers aim to reach a perfect integration (alignment) between digital and physical objects. However, the added value of these environments for educational purposes is instead their difference with reality. Walking through a dense forest of neurons is not possible in the world. In learning environments, the A of AR does not refer to visual overlay of digitally-generated and camera-captured scenes but to enriching reality with pedagogical properties. AR can make visible what is usually not visible, e.g. showing forces in the beam structure of a roof. AR allows non-realistic manipulations of reality such as changing the color of a flower, moving a planet or changing the season. In education, graphical realism is useful but not sufficient. What makes AR relevant is its partial freedom from raw fidelity, the opportunities AR offers to experience phenomena differently than the real world.

GERARD VAN DER STEENHOVEN

Professor Gerard van der Steenhoven is the general director of the Royal Netherlands Meteorological Institute (KNMI) since 2014. He is also a parttime professor Meteorological and Climatological Disaster Risk Reduction at the Faculty of Geo-Information Science and Earth Observation (ITC) at the University of Twente. Before this, he was the Dean of the Faculty of Science and Technology at the University of Twente. In that period he was also responsible for the start of the Twente Graduate School, which supports new researchers university-wide.

As the general director of the KNMI Van der Steenhoven is a board member of several international meteorological organisations such as WMO, EUMETSAT (chair), ECMWF, EUMETNET and ECOMET. He is an advisory board member of the Sonnenborgh museum in Utrecht, the Dutch Research Council NWO, the Royal Netherlands Institute for Sea Research NIOZ, and the NLingenieurs. He also participated in several audit committees related to program accreditation.

CLIMATE CHANGE TEACHING AND THE COVID-19 CRISIS

In almost every educational engineering program around the world some time is spent on sustainability. And when explaining the importance of sustainability as a design criterium, the motivation often includes some sections on climate change.

Introducing climate change in a lecture is as such not very difficult, as the effects (melting ice sheets, extreme weather events) are visible everywhere. Still, after such a lecture many questions are asked – which is good – on the soundness of the evidence and the relevance of the mitigation and adaptation measures proposed.

In this keynote lecture I will show how both the ozone hole observed above Antarctica since the '80-ies of the last century and the COVID-19 crisis we experience in 2020 serve as excellent examples on the reality of climate change. The key message being that these events unambiguously proof human influence on the chemical composition of the atmosphere. Moreover, these examples can also be used to show the effectiveness of mitigation measures. The importance of these two examples cannot be underestimated in the light of discussion on the Paris Climate Agreement of 2015.
The COVID-19 crisis brings suffering almost everywhere around the globe. This is clearly very regretful. In contrast to this, this worldwide crisis brings about educational innovations and advantages, which otherwise would have taken years to be introduced. For one, every student feels free to type a question in the chat box, not bothered by any social process going on in the group preventing her of him from posing the same question publicly. This reduced threshold may also apply to the usage of other digital tools aimed at increasing student participation.

Finally, I will take this opportunity to share with you some recent developments in climate change science which you should feel free to use in your own programs back home.

RUTH GRAHAM

A Mechanical Engineer by training, Dr Ruth Graham specialised in aeronautical fatigue, working with BAE SYSTEMS for a number of years. In 2002 she moved to Imperial College London, where she became Director of the EnVision project, which sought to transform the undergraduate education across the Faculty of Engineering and improve its culture of support and reward for teaching excellence. Ruth has worked as an independent consultant since 2008. Her work is focused on fostering change in higher education across the world; helping to improve teaching and learning and supporting the emergence of technology-driven entrepreneurship within universities. Ruth's recent projects have included a global benchmarking study on the future of engineering education, a multi-year initiative to improve the reward and recognition of teaching in higher education that is now supporting reform to the tenure and promotion systems of over 50 universities worldwide, and a cross-institutional teaching cultures survey, in which 20 universities are participating.

CELEBRATING AND REWARDING TEACHING: GLOBAL COLLABORATIONS FOR CHANGE

Despite a shared mission across the higher education sector to drive positive educational change, it is widely recognised that career advancement for academic staff rests primarily on their research profile. Such a research-centric university reward system imposes major barriers to innovation and change in engineering education. However, a growing number of universities are fundamentally rethinking the ways in which academic achievements in teaching are supported, evaluated and rewarded. Often working in collaboration with national or global peers, many are making fundamental changes to their academic career pathways and reward systems. Implementing such systemic reforms, however, are not easy. Their success often rests on whether the academic community trusts that these new policies will be delivered in practice by university decision-makers, as well as the alignment of wider institutional processes, such as annual appraisals. A new cross-institutional survey has been launched to monitor the perceptions and experiences of the academic community throughout the change process. Using three cross-sectional surveys, the Teaching Cultures Survey captures and tracks the perceived culture and status of teaching at universities across the world that are currently preparing for or already implementing systemic reform to their academic reward systems. The first set of survey findings, released earlier this year, shines a spotlight on the experiences and perspectives of teaching amongst the academic community as well as the opportunities and barriers to change.

The keynote will highlight the global advances made in reforming academic career pathways and improving the recognition of university teaching. It will also highlight findings from the 2019 Teaching Cultures Survey, in which over 15,500 academics participated from across 21 universities and 10 countries. It will conclude by discussing how the momentum for improving the recognition of teaching can be advanced and sustained in the context of the rapid shift to online teaching and learning resulting from COVID-19 restrictions.

RESEARCH PAPERS

ORDERED ALPHABETICALLY BY FIRST AUTHOR

EXPLORING STUDENTS' CONCEPTIONS OF VECTORS: A PHENOMENOGRAPHIC STUDY

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Conference Key Areas: **:** *Fundaments of Engineering Education: Mathematics and Physics, New Notions of Interdisciplinarity in Engineering Education*

Keywords: *vectors, phenomenography, variation theory, engineering mechanics, mathematics*

"He cannot, England know, who knows England only."
Ference Marton

ABSTRACT

The concept of vector plays a central role in engineering mechanics and strength of materials, where many quantities are vectorial in nature. Phenomenographic studies can be useful in revealing the different perspectives of the students' understanding of vectors and variation theory is a promising approach to improve the teaching of vectors. In this study, we will use the frameworks of phenomenography and variation theory to explore students' understanding and difficulties in using the concept of vector. The data consists of pre-, post- and delayed post-tests questions about vectors as well as student project reports in the course "Models, Mechanics & Materials", given to first-year engineering students, studying "Sustainable Design" at Aalborg University, Copenhagen, Denmark. The results of the pre-test suggest that most emphasis in teaching vectors in upper secondary school mathematics has been on the algebraic representations of vectors and less on their graphical representations, the mastery of which is essential to succeed in engineering courses such as mechanics and strength of materials. The results of the post- and delayed post-tests as well as the students' project reports showed some improvement in the

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students' performances after using variation- and context-based teaching of vectors in the course. The article concludes with some proposals on how the results of this study can be used to enhance the teaching and learning of vectors at the upper secondary schools and the university.

1 INTRODUCTION

Understanding many concepts in physics and engineering, such as force, moment and velocity, stands or falls on a firm grasp of the concept of vector [1]. Several studies investigate students' conceptions of vectors. For example, [2] investigated 2,031 physics students' understanding of vector addition, magnitude and direction. They prepared a list of questions about vectors in all introductory general physics courses at Iowa State University as pre- and post-tests. The outcomes showed that most of the students were unable to carry out two-dimensional vector addition after completing a physics course. [3] found that many students were not able to add or subtract vectors graphically after traditional instruction and could not answer qualitative questions about vector addition and subtraction. Their results are consistent with those of [2]: Students have difficulties performing basic vector operations. However, none of the previously mentioned studies investigating students' understanding of vectors utilized a phenomenographic perspective to design a lesson in vectors and to explore specific aspects in students' conceptions of vectors. This paper is an attempt to do so. Our empirical data consists of students' achievements on vectors through a pre-, post- and a delayed post-test as well as students' project reports in the course "Models, Mechanics & Materials", given to first-year engineering students in the years 2018-2019, studying "Sustainable Design" at Aalborg University, Copenhagen, Denmark.
Thus, the main purpose of the article is an investigation, using a phenomenographic perspective, whether the use of variation in teaching can contribute to improved learning of vectors. Variation theory is described below.

2 ON PHENOMENOGRAPHY AND VARIATION THEORY

How is it that two students who are sitting in the same class on the same day with access to the same materials can come to understand a vector (or any engineering concept for that matter) differently? There may be many answers to this question. ''Variation theory is a theory of learning and experience that explains how a learner might come to see, understand, or experience a given phenomenon in a certain way'' [4, p. 3391]. Variation theory stems from the phenomenographic tradition [5], which is an educational research method developed in the early 1980's by a research group at the Department of Education at the University of Gothenburg in Sweden [6]. It grew out of a series of empirical research studies that attempted to answer the questions ''(1) What does it mean that some people are better learners than others? And (2) Why are some people better at learning than others?'' [7, p. 146]. [6] asserts that there are a limited number of qualitatively unique ways in which different people experience or perceive the same phenomenon. Thus, the goal of phenomenographic research is to identify and describe the variation in experiences

or perceptions that students have of a given phenomenon. The phenomenon under study can *also* be a concept or an event.
Variation theory, sometimes referred to as ‘‘new phenomenography’’, reflects a shift within the phenomenographic research tradition that occurred in the 1990s [4]. During that time, phenomenography was criticized as being a purely descriptive and theoretical framework. In other words, although phenomenography and its methods could be used to identify and describe the range of experiences a group of people had with a given phenomenon, it could not explain *why* that variation in experience existed. Variation theory can be seen as a more theoretical extension of phenomenography, in that it attempts to explain how students (and generally, people) can experience the same phenomenon differently and how that knowledge can be used to improve classroom teaching and learning [8]. One of the most important tenets of variation theory is that seeing differences precedes seeing sameness [9]. The quote mentioned at the top of this document illustrates this claim: You cannot possibly understand what English is simply by listening to different people speaking English if you have never heard another language. Similarly, you cannot possibly understand what a vector is by only inspecting different examples of vectors.
To gain a complete understanding of a phenomenon, four different patterns of variation have been identified. These signify the difference between the aspects that stay invariant in a learning situation and those that do not. These are [10]:

1. **Contrast:** A person needs a point of reference to compare something with something else.
2. **Generalisation:** Variation in values of that aspect is necessary to discern the phenomenon.
3. **Separation:** In order to be able to separate certain aspects from other aspects, the phenomenon must vary while other aspects remain invariant.
4. **Fusion:** In cases where the phenomenon must be experienced in its entirety, it is necessary that a situation should be present where these aspects are all experienced simultaneously. Therefore, there is a fusion within the dimensions of variation of the specific critical aspects.

In variation theory, a teaching situation involves the intersection of two domains of knowledge and experience, *the teacher sphere* and the *student sphere*. The knowledge processed during a teaching situation can have three different outcomes [11]:

- The intended object of learning is what the teacher initially intended the students to learn.
- The enacted object of learning is what is made possible by the teacher for the students to learn in the lesson.
- The lived object of learning is what the students actually learn as a result of a learning situation. This knowledge can be analysed both individually and groupwise.

The following representation of the three forms of knowledge is the authors' own modification of the model proposed by [12, p. 210].

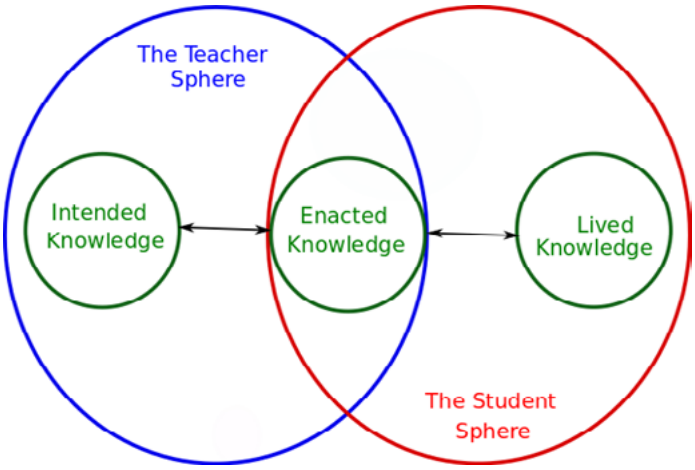


Fig. 1. The three different perspectives of knowledge in variation theory

3 STUDY METHODOLOGY

The participants in the study are 42 first-year engineering students, enrolled in the study program "Sustainable Design" at Aalborg University, Copenhagen, Denmark. We chose these students because of convenience in sampling and also because the topics of the course can be found in many engineering programs. The students were given a pre-test in the first day of class of the course "Models, Mechanics & Materials", held in the Fall semester 2018. The first author was the lecturer in the course. The pre-test includes many questions about basic topics from upper secondary school mathematics, including the following two questions about vectors:

1. By referring to Fig. 2 below, it is given that $|\vec{a}| = 4$ and $|\vec{b}| = 3$. Sketch the vector $\vec{a} + \vec{b}$ and calculate its length (numerical value).
2. By referring to Fig. 3 below, it is given that $|\vec{a}| = |\vec{b}| = 5$. Sketch the vector $\vec{a} - \vec{b}$ and calculate its length (numerical value).

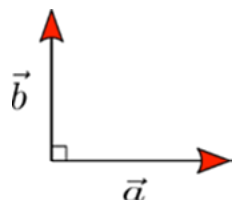


Fig. 2. Two perpendicular vectors

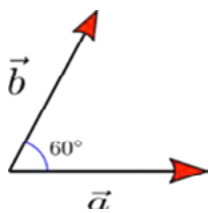


Fig. 3. Two oblique vectors

These questions are chosen because they represent some *critical features* of a vector (in contrast to a scalar, for example). The post-test and the delayed post-test consist of the same questions as the pre-test. The post-test was conducted at the end of the course in December 2018, where the students also had to submit a group report in the course project. The same class received the delayed post-test at the end of the Spring semester in June 2019.
The results of the tests are collected and analysed, while the students' project reports are made accessible on Aalborg University learning platform, *Moodle*.
Assessing the students' prior knowledge through a pre-test would make the students aware of the contents they are expected to learn and can potentially influence the learning experience of the students [13].
The purpose of the delayed post-test is to analyse the lived knowledge of the students as well as to enable the researcher to see whether the changes in knowledge have a long-term effect or only a short-term effect of the lesson. As educators and researchers, we are naturally interested in developing sustainable learning, since tests given directly after the lesson are not indicators of long-term change in the students' experience.

4 LESSON DESIGN

According to variation theory, the role of the teacher is to design learning experiences for students to make it possible for them to discern the critical features of the object of learning [14, p. 195]. However, variation in teaching does not guarantee that the student will in fact discern the object of learning at stake, as discerning depends on the student's previous knowledge, current state of mind, interest in learning, etc. The curriculum of the course Mathematics A at the upper secondary education in Denmark (highest level) involves an introduction to two-dimensional vectors [15], mainly in coordinate form. Examining some textbooks that implement the curriculum, for example [16], the authors found that the concept of vector is used merely as a synonymous of free vector, which is not enough for the university students to discern all the critical features of a vector, as applied in the course. Variation is therefore needed to discern those aspects of vectors not previously discerned by learners. Using variation and simultaneity between aspects, the students can learn to see vectors in new ways.
Presumably, the students have studied vectors as quantities having both a magnitude and direction in contrast to scalars, which only have a magnitude. Below we give excerpts of the actual lesson on vectors given by the first author. We started by reminding the students of what they have learned about vectors and scalers by giving examples, as in the following figure:

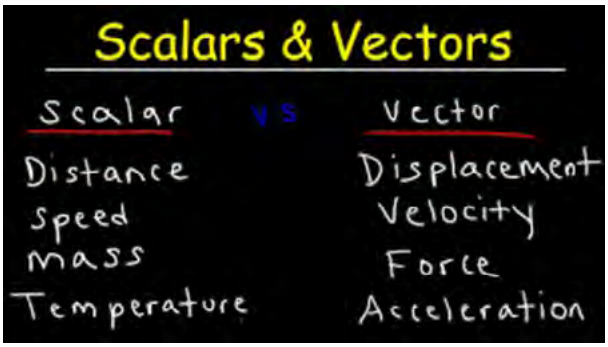


Fig. 4. Scalars and vectors

We then asked the students to *compare* and *contrast* the vectors in the following two figures. In Fig. 5, the velocity of the rocket test sled is a *free vector* since the velocity is the same at all points in the sled whereas the two force vectors in Fig. 6 are *fixed* (or *bound*) since changing their positions will alter their effects on the mattress. The velocity vector in Fig. 5 corresponds to the *mathematical* definition of a vector (read: *free vector*). In Fig. 6, the two aspects magnitude and direction remained *invariant* while the point of application varied. This situation corresponds to the *separation of aspects* in variation theory.

Fig. 5. A free vector

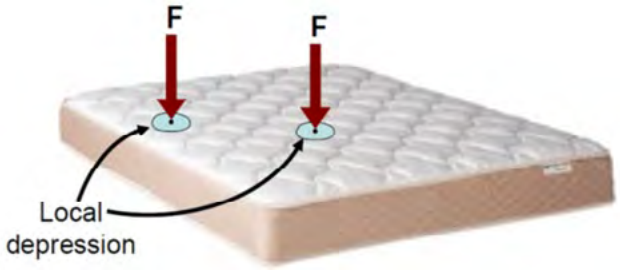


Fig. 6. Fixed vectors

We then showed the students two different examples of a *sliding vector*. In Fig. 7, the four cable forces can “slide” along their respective lines of action, *along* the cables, similar to the weights of the two traffic lights in Fig. 8 which can also “slide” along their respective lines of action, but *perpendicular* to the horizontal beam.

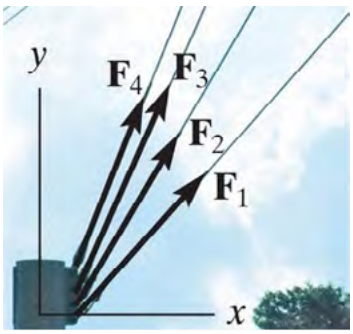


Fig. 7. Sliding vectors (I)

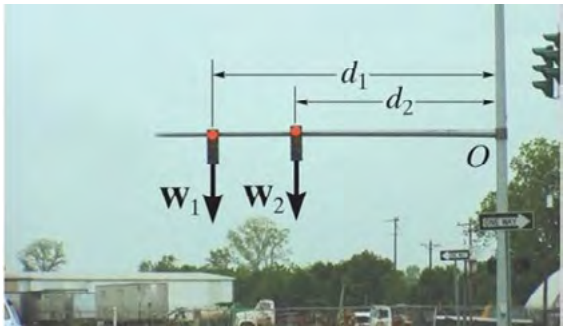


Fig. 8. Sliding vectors (II)

A *fusion of all aspects* of a vector results when we *generalize* the mathematical definition of a vector, by giving our own definition:

- A vector is a quantity that has a magnitude, direction, line of action *and* a point of action.
- If the line of action does not pass through a certain point in space, the vector is called a *free vector*. It is freely movable in space
- If the line of action is fixed, the vector is called a *sliding vector*. It does not have a unique point of action.
- If the point of action is unique, the vector is called a *fixed vector*.

5 RESULTS OF THE STUDY

The focus of this section is on whether teaching vectors using variation theory has contributed to improve the students' understanding of some critical features of vectors. 42 students took the three tests, but only 40 answered to the delayed post-test.

Table 1. Distribution of conceptions between Pre-, Post- og delayed post-test

Student conception	Pre-test scores	Post-test scores	Delayed post-test scores
1) Sketching $\vec{a}+\vec{b}$	70%	91%	74%
2) Finding $\lvert\vec{a}+\vec{b}\rvert$	72%	80%	79%
3) Sketching $\vec{a}-\vec{b}$	27%	61%	53%
4) Finding $\lvert\vec{a}-\vec{b}\rvert$	20%	39%	32%

Table 2. Mean and standard deviation (SD) for students' achievement in the three tests

Test	Mean	SD
Pre	1.86	1.08
Post	2.80	0.97
Delayed post	2.2	1.05

In order to find out if the differences between the scores of the pre-test and the delayed post-test were significantly different, or not, a paired *t*-test was conducted:

T Test, Difference of Means

	Sample 1	Sample 2
Mean	1.86	2.2
s	1.08	1.05
N	42	40
SE	0.2352	
df	79.964	
t	-1.4454	
P	0.0761	

Fig. 9. Results of a statistical test to compare the two means of the pre-test and the delayed post-test

As seen in Tables 1 and 2, the students achieved significantly better test scores in the post- and delayed post-tests than in the pre-test although the delayed post-test scores were all a little below the post-test scores. For example, there was a considerable increase in the students' scores on sketching the difference vector $\vec{a} - \vec{b}$ from 27% in the pre-test to 53% in the delayed post-test. A close look at the results of the pre-test showed that many students who gave wrong answers in finding the length $|\vec{a} - \vec{b}|$, have erroneously used Pythagoras' theorem to calculate the length, which they have previously learned in connection with finding the length of a vector, given in coordinate form. This would suggest that the geometrical aspects of vectors were given a minor role, whereas the *algebra* of vectors is much more dominant at the upper secondary school. In fact, the length and direction of a vector are critical geometrical features of a vector that cannot be discerned *merely* by using vector coordinates.

The paired *t*-test (Fig. 9) found the *p*-value to be 0.0761, which means that we can reject the null-hypothesis that the mean difference between the two sets of answers is zero at a 10% significance level, but not at a 5% significance level. Thus the students did in fact score somewhat higher in the post-delayed test on average.

It seems, therefore, that using variation theory as a lesson design tool *together* with teaching vectors in the *context* of statics and strength of materials would improve students' learning in vectors. This study imparts some empirical evidence that support the use of variation theory as a pedagogical guide to design lessons in vectors in the classroom.

In the figures below, we show excerpts of some students' answers.

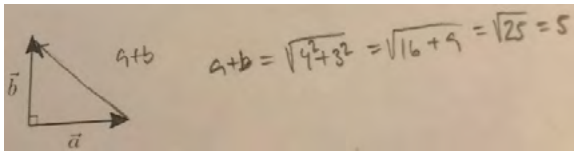


Fig. 10. A student solution for finding $\vec{a}+\vec{b}$ in the pre-test. The length is however correct

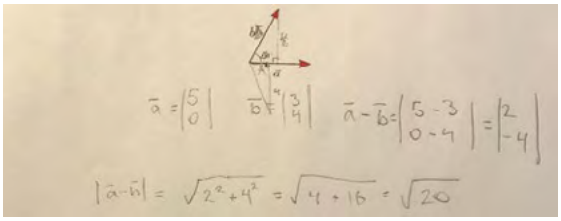


Fig. 11. A student solution for finding $|\vec{a}-\vec{b}|$ in the pre-test. Notice the use of coordinates and Pythagoras' Theorem

Fig. 12. A student solution for finding $\vec{a}-\vec{b}$ in the pre-test

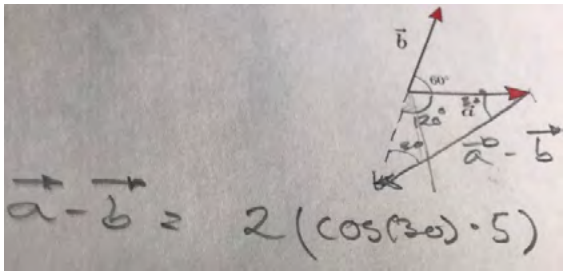
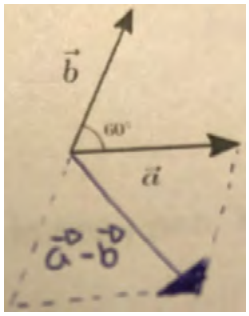


Fig. 13. A student solution forfinding $\vec{a}-\vec{b}$ in thedelayed post-test



6 CONCLUDING REMARKS AND DISCUSSION

Variation theory is a promising tool for investigating students' conceptual understanding. However, the authors find that the theory ignores the effects of the students' prior knowledge on the lived object of learning. In fact, some studies have shown that the students' prior knowledge affects their learning when comparing multiple examples in teaching [17]. The students' prior knowledge itself could be thought of as a pre-lived object of learning, while students' understanding of the object of learning after the learning event takes place could be a post-lived object of learning. However, each individual encounters a unique set of experiences that shapes a unique cognitive framework and guides the perception and integration of new knowledge within the individual. Thus, prior knowledge is an important element in the construction of conceptual knowledge [18]. That is why we decided to integrate the students' prior knowledge about vectors to construct a new understanding of vectors, which itself becomes part of the students' prior knowledge for afuture learning experience. As seen in Tables 1 and 2 and Figure 9, the results of the delayed post-test seem to suggest that the students did not fully retain what was learnt, but the fact that a lot was retained means that this knowledge would indeed

become part of the pre-lived object of learning. Furthermore, when the students took the delayed post-test, they were busy with the actual exams and motivating them to take this test for the benefit of research was not easy, which might also explain the drop.

In this regard, the authors suggest that the curriculum of vectors in Mathematics A at the upper secondary schools and in engineering mathematics courses should include all kinds of vectors that the students will encounter in science and engineering, given the fact that many students enrolled in Mathematics A will study science, mathematics, engineering or technology at the university.

Since instructional materials, including both physical and virtual resources, are designed to facilitate learning [19], they can have an unintended influence on the enacted object of knowledge. Therefore, the authors call for the inclusion of more examples on the geometrical aspects of vectors and their applications in physics and engineering in upper secondary mathematics textbooks.

7 FUTURE RESEARCH PERSPECTIVES

Recent research studies reported that the integration of variation theory in classroom instruction improves students' performance significantly [20, 21]. Considering the success of the integration of variation theory in teaching vectors, it is possible to combine variation theory, *animations* and Problem-Based Learning (PBL) in major topics of the course, such as equilibrium of rigid bodies, materials behaviour and stress analysis, by allowing students to construct their own knowledge. Studying the different forms of the objects of learning during their three phases: the intended, the enacted (read: *constructed*) and the lived, and the influence they would have on the learning outcomes of the whole course, would be an interesting subject for a future article.

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EXTENDED REALITY IN STEM EDUCATION: ADVANCES AND CONSIDERATIONS

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ABSTRACT

Technology is impacting education in a number of ways. Examples include the advent of online education, maker tools such as the Arduino, and software such as intelligent tutors. Within this context, MIT Open Learning is working on understanding, supporting, and further developing the role of computer-based immersive learning technologies including augmented, mixed, and virtual reality systems (collectively called extended reality, or XR) in education. XR has often been positioned in the market as the next disruptor that will revolutionize STEM education. Such immersive learning systems have the capacity to support learners not only in knowledge, skill, and tool mastery, but also with engagement in STEM subjects (affect), seeing oneself as a STEM practitioner (identity), broadening participation through cultural customization (diversity), communicating as a STEM professional (discourse), and more. However, many crucial challenges, related to bringing XR to class are seldom considered. In a review of literature over the last 5 years, and augmented by our own studies, we find that some aspects of immersive learning systems have been evaluated usually in isolation, without comparative analyses with other teaching modalities, and without long term analysis to correct for the novice effect. We recommend advances on 5 fronts: interdisciplinary collaborations, comparative research, in-depth exploration of learning implications, development of new research methodologies, and institutional and organizational change.

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1 INTRODUCTION

Traditional educational research focused for decades on understanding and evaluating the educational content, the classroom setting, and the behaviors and interactions that might occur in class. The advent of the internet along with the rapid development of online educational technologies has been disruptive in the last three decades. New content, new pedagogies, new policies, and new degrees are now steadily developed and adopted by a great number of educational institutions around the world [1,2] As it has previously been stated in the MIT-OEPI Report [3], it is imperative that this massive development in the field of digital learning gets paired with extensive deeply integrated research across all fields that impact learning. Within this context, MIT Open Learning is working on understanding, supporting, and further developing the role of computer-based immersive learning technologies [4-6] including augmented, mixed, and virtual reality systems (collectively called extended reality, or XR) in education.

XR has often been perceived as the next disruptor that will revolutionize STEM education., as it is expected to support pedagogical innovation, enhance distant learning, as well as demoratize access to education. The rapid development of such technologies and the large number of learning related XR applications, which are rising daily in popularity, seems to support this notion. However, such immersive learning systems have the capacity to support learners not only in knowledge, skill, and tool mastery, but also with engagement in STEM subjects (affect), seeing oneself as a STEM practitioner (identity), broadening participation through cultural customization (diversity), communicating as a STEM professional (discourse), and more [6,7].

1.1 Potential Impacts of XR in Education

XR educational technologies, in particular fully immersive VR systems, have long been described as new media with the potential to support revolutionary new approaches to education if incorporated apropreately within a well orchestrated educational ecosystem. There are many definitions of “immersion,” however for the purposes here we mean: “An immersive environment is one that generates perceptual experience of the environment from a perspective within it, giving the user the sense of “presence”: that is, the sense of really being present at that perspective”[8]. The ability to immerse in a new reality is expected to allow teachers and students to break current barriers and overcome restrictions [9-13] such as:

- Time: Students can now travel in time and experience simulations or documentation of past historical places or speculative future.
- Physical inaccessibility: Students can explore the macro and micro worlds, e.g., travel to the moon or visit the interior of a molecule.
- Physical or psychological danger: Students can now safely train in simulations of hazardous situations like a fire or a flood; or safely place themselves in a

position that might bring new or even uncomfortable types of social interaction.

- Ethical problems: Students with no prior experience can now try performing a difficult surgery.
- Cost limitations: Students can now use virtual laboratories and run virtual experiments with sensitive and costly equipment they would not have been able to access otherwise.

In addition to the aforementioned cases, through XR students are expected to be able to virtually collaborate with peers physically located elsewhere, or even with non-existent virtual characters [10]. Furthermore, they are expected to engage with virtual identities they might never encounter in the physical world (avatars, characters, agents, etc.) and to have the chance to embody them in order to explore models of experiences beyond those they would encounter through their physical world current age, race, sex, or even species [4,14-17]. Research on the effects of social identities has also shown that use of XR can positively impact aspects of social educational issues, such as stereotype threads, through the appropriate employment of role-model avatars. All these affordances have also created the hypothesis that XR environments will help raising student motivation, engagement and participation [18], hopefully leading to better and deeper learning.

Having all that said, it should be clearly noted though that it is also common knowledge among the academic community [19,20] that the use of VR technologies "for creating learning environments holds a great promise but also many challenges"[20-21]. Despite the great interest and the high hopes surrounding XR system in education, it quickly became obvious that very few instances of the educational content, and experiments evaluating their impacts, have been designed with a clear pedagogical frameworks or even particular learning theories in mind. Furthermore, although XR are presented as the solution that will advance students learning, many crucial challenges, related to bringing XR to class are seldom considered. Within this context, MIT Open Learning understands and feels the responsibility to draw special attention to the fact that only a very small number of these technologies has been properly researched and evaluated yet, therefore highlighting the great need for extensive research related to the development of the field.

2 METHODOLOGY

2.1 Data Collection and Analysis

Current paper presents a literature review on papers related to XR in education. To collect papers included in the study, the authors conducted a search on scholar.google.com looking for "Virtual Reality in Education" and "Augmented Reality in Education" and selected the conference and journal papers that were published within the last 5 years (from 2014-2019). To further demonstrate some of our own

contributions to the area, the authors additionally included publications produced by the faculty and researchers involved in the MIT Center for Advanced Virtuality. A total of 59 conference and journal papers were considered for this study. When reading the papers authors aimed to identify research studies that would mention a particular pedagogical framework or learning theory, or evidence related to retention of learning.

3 RESULTS

3.1 Pedagogical Principles

To date, the majority of XR educational technologies are applications introducing AR elements to complement and enhance traditional teaching resources. However, as VR equipment becomes more affordable and accessible (for instance, mobile VR systems that require only inexpensive plastic or even cardboard headsets and a mobile phone), new content introduced through VR worlds has been developed at an increasingly rapid pace. Most of the times content is not designed with a clear pedagogical framework in mind, but in cases where pedagogies are mentioned or can be clearly implied, the most common among them seem to be constructivism, active learning, collaborative learning, experiential learning, situated learning followed by kinesthetic learning and embodied cognition. As new technology is developed and more elaborate immersive experiences are provided for learners, a new learning phenomenon also emerges that must be theorized, which is implicit learning through embodiment. According to early studies testing this theory, different virtual body ownership “can result in implicit changes in attitudes, perception and cognition, and changes in behavior”[22]. Furthermore, as argued literature, previous research has demonstrated that the way users behave in both the physical and virtual worlds can be influenced by these virtual self representations”[4].

3.2 Relevance Across Educational Settings

Examining current literature shows that XR content has already started to be developed for a great number of subject matters and educational levels. Although computer simulations, later developed into more elaborate VR immersive worlds, have been traditionally used in medical education, military education, flight training, and training of personnel to possibly face emergency situations, ready to use content can now be found for many K-12 or higher education courses.

3.3 XR in K-12 Education

Taking a closer look at XR resources and technology for the K-12 education level, it appears that the majority of content developed constitutes AR applications that run on mobile phones or tablets, followed by 3D non-immersive games and simulations, and a small number of immersive VR educational worlds. Content most of the time was presented in the form of exploration or simulations. Meta-analysis of 69 related studies [23] including K-12 and higher education students showed that when comparing games, simulations, and virtual worlds to one another, games played

individually showed higher learning gains in comparison to the other two cases; researchers however also found an inverse relationship between number of treatments and learning gains. In alignment with that result, researchers also found that when students were repeatedly measured when using a virtual world, this seemed to deteriorate their learning outcomes gained. Furthermore, although most of the studies mentioned positive learning gains, many of them had several research limitations or did not providing adequate statistical information to support the effect sizes. In addition to the aforementioned studies, research comparing physical artifacts to an AR enhanced digital book, and to 3D virtual objects showed that elementary school children reported preferring the AR book more than the other two options. Other studies examining AR and VR in K-12 show that without proper guidance students tent to find this technology to be very overwhelming , complicated, and creating too much extra cognitive load especially to students scoring in the lower quartile on standardized exams. In addition to the lack of extended research on learning through XR at the K-12 levels, there is also a very noticeable gap in the literature in regards to the teacher experience when teaching using XR technologies. There is a similar gap regarding learning for children with special needs. At this point, it should be mentioned that the vast majority of XR resources are developed for upper elementary classes and beyond; which is in complete alignment with the fact that there is still great lack on research that can prove safety and appropriate use for children at the early education level, especially after dizziness, disorientation, and nausea have been frequently reported by many children when using VR equipment (indeed, popular VR systems typically include warnings deprecating their use with young children).

3.4 XR in Higher Education

A variety of XR resources has already started to be developed for the higher education level recently, making content for many subject matters now available. AR is usually integrated in class via “tools to track information about real-world objects of interest; hardware and software to process information; and devices to show the user the digital information integrated into the real environment”. VR seems to become mainly introduced either through educational games or simulation applications. Virtual medical labs and operation room are also increasingly deployed. Moreover, development of VR technologies “is starting to spread its influence to the AECO (Architecture, Engineering, Construction and Operations) sector through the creation of new work methodologies and techniques, as well as original interfaces for communication” [24]. In rarer cases, one can find courses introduced through venerable CAVE systems. As previously discussed, the limited research conducted in regards to the use of XR in higher education brings to light some encouraging indicators related to student motivation or peer collaboration, however most of the content and application developed so far rarely contain explicit pedagogies or mention a clear learning framework.

3.5 XR in Professional Training

Use of XR technology for professional training already has a long history, new tools though do get more and more elaborate over time as new technologies emerge. Augmented simulations have been long used in the fields of military and pilot training. Medical training has now been using plenty of XR content and platforms where doctors can either simulate difficult operations, get a view inside the patient's body, or even interact with virtual patients in order to learn how to deal with stressful situations, or just to understand how to further develop empathy with a patient. Moreover, content has now started to get developed for professionals who work in the construction field, or for personnel that has to deal with emergency situations and natural disasters. Virtual enviroments and online learning systems can also be used to provide workplace training on social issues such as sexual harassment and more broadly for reflective learning (in which reflection and perspective transformation are measured, not only employee completion rate). Finally, VR has started to be used in the field of traditional education for teacher training, as teachers can now interact with a virtual classroom and practice teaching under different scenarios. Having that said, it should be pointed out that there is again a lack of extended comparative studying and evaluation in regards to most of the commercial training applications that can currently be found on the market.

3.6 Research methods employed

Although various research groups have started conducting studies relevant to XR Education, up to date most of these studies are small scale research studies that only focus on understanding the use of a small educational module used within a small group of users. Such studies may provide some initial indicators in regards to whether an AR or VR module might be working for a particular group of learners, however it does not allow us to know if it works better than other more traditional approaches.

4 CONCLUSION AND RECOMMENDATIONS

4.1 Recommendation 1: Increase Interdisciplinary Collaboration Across Fields, Using and Integrated Research Agenda

Although the need in higher education for deeper integration of research across the fields that impact learning [3] had already been highlighted and justified, we now state the need for such collaborations through the prism of the development of XR educational spaces at all educational levels. The suggested interdisciplinary scheme (Figure 1) would involve a large number of disciplines. Collaboration across these fields will continue strengthening our understanding of how learning works and will keep helping improve the design, development and evaluation of effective learning experiences. To develop and study these new educational worlds we need to combine the fields of the learning sciences, education, technology development, game design and development, arts and design, and health studies just to mention a core few. All these fields have been showing great advances when studied

individually in the past, however it is the carefully orchestrated highly interdisciplinary collaboration that now needs to come to play. We recommend that institutional and government agencies, as well as other foundations supporting learning and education research, to highly encourage development of much wider and cross-disciplinary research schemes that will allow for deeper exploration of these new fields.

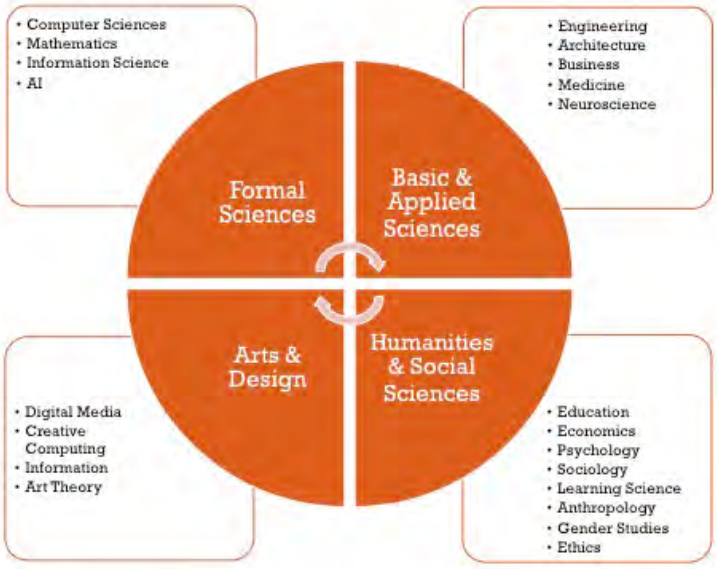

Fig. 1. Fields that need to be integrated during the design of XR Education

4.2 Promote Comparative Research and Evaluation of Technologies and Pedagogies as the Critical Factor to guide Future Development and Decision Making

Having carefully examined the current landscape of XR in education, it becomes clear that development of new technologies does not always get followed by careful research-based evaluation. Even when there is a follow-up study, it almost never presents a comparative testing case including control groups. At the cognitive level, even when studies present encouraging findings regarding learning, access, and participation, there is almost never a comparative testing case that would allow us to fully understand the benefits of this new teaching method over the use of a simple 2D computer simulation or just the delivery of a traditional lecture. Given current challenges already mentioned, we recommend that a) researchers closely attempt to collaborate and coordinate their studies with XR developers, so they can carefully design long term research studies, and b) carefully plan comparative experiments between control groups using XR and more traditional teaching methods. Furthermore, although we hypothesize some of the immediate benefits of using XR in education, such as the fact that it almost always sparks interest and enthusiasm among the students, it is still unknown to us when this novelty effect starts to wear off. It is, of course, understood that in order to study the novelty effect one should be able to use resources for an extended period of time, not easy in this case, given

that, especially regarding immersive VR educational worlds, existing resources mainly include individual or short scale modules while we still lack content that could support long term curricula.

4.3 Allow Time for In-Depth Exploration of the Field

Since XR in education is an area still in its infancy, we believe that a substantial amount of time will be required in order for researchers to properly understand and evaluate potential benefits and threats to student learning, as well as to school logistics and performance metrics. Despite the fact that XR technologies have now become more affordable, allowing for a big number of K-12 teachers, higher education instructors, and professional trainers to currently use them in class, only a very small number of short-term evaluation studies have been published up-to-date, leaving a great number of essential questions unanswered. Acknowledging all potential benefits, but also keeping in mind all potential threats, mainly cognitive, social, and physical, but also related to cybersecurity or missuse of student personal data. MIT Open Learning recommends that instructors and institutions proceed with critical awareness when incorporating XR in class, while constantly keeping themselves informed regarding updated research findings in the field.

4.4 Support the Development of new Research and Evaluations Methods

Educational studies had traditionally been using some well-established qualitative, quantitative, and mixed research methods, that would mainly employ an *external* observer/interviewer view in regards to studying human learning. During the last years MIT's agenda, through the development of the MIT Integrated Learning Initiative (MITili), is to promote a deeper integration of all learning related sciences, attempting to create a more holistic research scheme that would combine the traditional *external* view with the *internal* view usually employed by the brain and cognition and the neuroscience field. Considering how multidisciplinary *XR in education* is expected to be (Figure 1), one can expect that a great number of already existing research methods and evaluation instruments can already come to play, such as, but not limited to, a) observational protocols (mainly used at the fields of the learning sciences and cognitive psychology), b) CT or EEG scans (mainly used in the field of cognitive science), c) software usability evaluation tools (mainly used at the fields of human computer interaction and software engineering), d) cost efficiency and scalability analysis tools (mainly used in the field of finance). All the aforementioned methods and tools can already be used in order to measure different aspects of this upcoming educational world; however the need for new, advanced, more integrated assessment and evaluation instruments, that would also allow us to interconnect and correlate findings from all these different research worlds into meaningful answers, is very critical and therefore should be fully supported for the further development of the field.

4.5 Foster Cross Institutional and Organizational Communication Schemes to Facilitate Information Sharing as New Technologies and Pedagogies get Implemented and Evaluated

Although XR in education is still relatively embryonic, organizational approaches and implementation mechanisms that will eventually be employed to introduce potential XR applications can already start getting carefully designed and formed. In particular, we recommend the creation of *thinking communities* to continuously follow, internally evaluate, and disseminate information about XR educational innovations as they will get developed; and the identification and development of *change agents* and *role-model early adopters* in assisting the K-12, higher education, and professional education communities into adapting and implementing upcoming XR tools and pedagogies. Here, we refer to change agents as groups of experts, each time specialized in an appropriate educational level, collaborating toward a common end, rather than just individual visionaries [3]; and to role-model early adapters as successful groups, K-12 schools and academic institutions that are willing to pilot new, thoughtfully designed approaches [3].

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AN OVERVIEW OF THE SITUATION OF PROJECT-BASED LEARNING IN ENGINEERING EDUCATION

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ABSTRACT

Project and problem-based learning are gaining a solid ground in engineering education. There are well-known communities such as the CDIO organization that promote a certain curricular framework for projects. There is also a large but scattered research literature that reports various ways of implementing projects. However, a comprehensive situation analysis is still waiting to be written. This paper aims to draft an overview of the current situation in Europe. A recent research review by Chen, Kolmos & Du has collected a considerable amount of scholarly articles on the subject, however, much of the current practice is not included or exposed in their paper due to the focus on challenges. We attempt to enhance the understanding of the current situation by adding information that is found in conference papers such as of SEFI annual conferences, university publications and web-sites, Erasmus project information, and so on. The scholarly literature covers only a part of the practice because most of it is ongoing activity that is not organized as research projects; therefore, to understand the situation various kinds of sources of information are needed. Our goal is to increase understanding of how PBL is reported, experienced and developed in European universities, based on previous studies and our own explorations.

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1 INTRODUCTION

1.1 Aims

Project and problem-based learning are gaining a solid ground in engineering education, particularly in some geographical areas such as Northern Europe. There are well-known global communities, most prominently the CDIO organization that promote a certain curricular framework for projects (http://cdio.org). Additionally, the project-based approach promoted by the Aalborg University has a base of followers. The extensive research literature that reports various ways of implementing projects is scattered in journals and conference proceedings of many sub-fields of education and engineering. This paper specifically aims to outline an overview of the current situation in Europe. A recent research review by Chen, Kolmos & Du [1] has collected a considerable amount of scholarly articles on the subject with an emphasis on challenges and difficulties. Nevertheless, much of the current practice is not included or revealed in their paper. The scholarly literature covers only a part of the educational practice because most of it is not organized as research projects; therefore, to understand the situation also other sources of information are needed. We attempt to enhance the understanding of the current situation by adding information that is found in conference papers such as of SEFI annual conferences (http://sefi.be), university publications and web-sites, Erasmus and EU project information, and so on. Our goal is to increase understanding of how PBL is reported, experienced and developed in European technical universities, based on previous studies such as the work by Chen et al [1] and our own explorations.

1.2 Related studies and reviews

The common acronym PBL could refer to project-based learning, but maybe more often it refers to problem-based learning. These two approaches sometimes overlap even though the motivations and pedagogical thinking differ, which will be discussed later in this paper. Problem-based learning has a long history in medical education and in primary and secondary schools [2]. It has its own journals such as The Interdisciplinary Journal of problem-based learning and The Journal of Problem Based Learning in Higher Education. We do not intend to define what is understood by project-based learning, which is a rather vague concept, instead, we rely on the reports by the universities themselves. Moreover, there are several other terms that refer to approaches that include similar ideas and practices such as supported collaborative learning, inquiry-based learning, and team-based learning.
Edström & Kolmos have written a thorough comparison of the two major solutions for higher education (HE) project-based learning, namely the “Aalborg model” and the CDIO initiative in engineering [3]. Therefore, we do not repeat the details of the models here, but refer to their paper, and numerous other articles covering the motivations and findings of either of those solutions, some of which can be found in the references of this paper. A brief outline is given in the chapter 3 that presents the different ways to include projects in the curriculum.

1.3 Sources of information

This paper aims to shed light on the phenomenon of project-based learning, particularly in recent years in Europe. It is based on a variety of sources: literature surveys on scholarly articles, other published materials, visits to several universities, collaboration in EU funded projects and exchange programs, and meetings in various conferences on engineering, education and for information technology professionals. The authors have been active participants in a number of EU funded and Erasmus projects and programs over twenty years, which has helped to build a network of colleagues and get insights to practices in European countries (https://ec.europa.eu/programmes/erasmus-plus/projects/). Because the home base of the authors is in Finland, Finnish universities are used as examples for various practices. As Finland has a small population of less than 6 million, but a large land area, it has relatively many technical universities (7) and universities of applied sciences (18). They collaborate widely in developing the education, and therefore share many best practices, some of which are described here.

2 WAYS OF IMPLEMENTING PROJECT BASED LEARNING

2.1 Motivations for projects as parts of curriculum

The motivations to start using projects in higher education are varied, starting from educational ideas to purely commercial aims. Professional practices in engineering have inspired many project courses, where the intention is to build professional skills. Engineering practices include much project work, and whenever a new product is built, the process is organized as a project: It could be a construction project, software project, designing an aircraft project, and so on. Therefore, learning about problem-solving through projects is an essential part of professional competence and needs to be a part of any engineering curriculum. [4] [5]

Engineering faculties have been involved in research and development (R&D) work and collaboration with companies for decades. Universities strive to build collaboration with local and also global companies for several reasons. Sometimes they are promoted by government policies, or the goal is to improve employment possibilities of their students, sometimes simply to make money in a situation where funding is insufficient. The collaboration may take many forms, one form being student projects where a company acts as a client. The so called innovation centres and labs are the latest trend in these activities. Collaboration with industries is typical in cities that have large manufacturing and R&D facilities, such as Stuttgart in Germany (car manufacturing) or Espoo, Oulu and Tampere in Finland that had Nokia R&D centres. In Jyväskylä in Finland, the university and IBM have a shared innovation hub. The Metropolia University of Applied Sciences has an R&D unit called Electria which started with a sterile manufacturing lab and RFDI development before expanding to scaffolding start-ups under the Turbiini project.

Pressures from the government and local actors include programs by European Regional Development Fund (ERDF) and the *European Social Fund* (ESF) that encourage involvement with city planning, and civil society. Technical universities act

together with cities and NGOs to develop new solutions in projects where also students participate. When the primary goal of projects is something else than education, the additional value for students would probably need more attention than it usually gets. However, efforts such as the European Network of Living Labs (ENoLL) strive to combine innovation activities with solid educational principles. (http://enoll.org)

Additionally, universities are expected to provide entrepreneurial skills to students. Hands-on experience is definitely the most efficient way to get an understanding of entrepreneurship. Universities have established business incubators, innovation laboratories, etc. where students can experiment with start-up business in instructor-led projects. Often this is organized as multidisciplinary work with other fields of study where technical skills can be combined for instance with health care or environmental expertise. The Oulu University of Applied Sciences in Finland has developed a prototyping program called OAMK LABs. The LABs are structured as interdisciplinary, full-time programs that bring together teams to develop new products and start-ups. The Oulu EduLAB brings teams together to develop global education technology solutions, many of which are educational game prototypes [6]. Sheffield Hallam University in the UK is another case that widely applied collaboration projects with local entrepreneurs. [7]

Internal motivations for curriculum development include efforts to improve retention, which has been a longstanding challenge at technical universities. Even half of engineering students drop out from their studies at some universities. Numerous efforts to remedy the situation have been tried and reported. Student motivation has suffered from initial physics and mathematics studies that lay ground to scientific understanding but are demanding and the connection to professional practice has remained unclear for the students. Student projects have been an effort to make the studies more engaging. Projects that combine various skills have been one way to soften the beginning of the studies and to increase the motivation. The CDIO initiative can be considered as one of the major efforts to tackle this issue. [5]

2.2 New learning technologies

Online learning platforms include increasingly sophisticated tools for collaboration and project work. Moreover, many business oriented applications are suitable for team efforts in distance learning. These enable various experiments with international student groups from several universities, which have also been reported in research literature usually as case studies. A large number of them are connected to EU funding (Erasmus) that requires partner collaboration in several countries. On the other hand, open virtual universities apply platforms where project or team work is one optional mode of instruction.

Moreover, there have been projects that have particularly aimed at developing virtual collaboration tools that support project work. Early efforts include the Netpro in 1998 supported by EU by the EVTEK University of Applied Sciences in Finland in collaboration with several other European universities [8]. It was later followed by Knowledge-Practices Laboratory (KP-Lab) with University of Helsinki and 20 other

European universities in 2006-11. As a theoretical innovation, the KP-Lab represented an approach to human cognition that went beyond acquisition and participation metaphors of individual learning into shared knowledge-creation processes. The KP-Lab organized courses that focused on solving complex problems for professional communities in participating companies. The KP-Lab built reflective social practices around shared knowledge artefacts of technology-enhanced learning. [9]

2.3 Educational goals and backgrounds

Educational ideas, based on cognitive science and learning theories, have inspired new methods frameworks for improving learning such as the KP-Lab described above. The idea of problem-based learning is partially related to critical pedagogy by Paolo Freire, whereas project-based learning is anchored in the constructivist theory of learning and cognitive learning theories that originate in Vygotsky's thinking and cultural historical activity theory developed by Leontjev, Wertsch and Lave. [2, 10] Nevertheless, project-based learning efforts in engineering seldom are that well informed on human cognition and learning, as the instructors tend to have less background knowledge in educational theories, having technical professional education themselves, and less regularly pedagogical training. Many efforts are built on "best practices" kind of thinking, and new ideas are found by benchmarking other institutions. [11]

2.4 Educational theory

Collaborative learning and problem-based learning are strongly anchored to educational research, cognitive psychology and theories of social construction of knowledge.
Inquiry-based learning and trialogical learning are related concepts that have been referred to in various implementations of project-based learning. The technical university of Eindhoven calls its approach Challenge Based Learning (CBL) [2]. Learner-cantered approaches are supported by the current knowledge of human cognition by neuroscience. Humans build their knowledge in continuous interaction with the environment, other people and learning artefacts. Learning is an active process of problem-solving, adoption and creation of knowledge and skills, based on existing competences. At universities, the knowledge creation process is additionally connected to expert communities and social networks. [9]

3 RESULTS

3.1 Various types of implementation

The implementations of project-based learning can be roughly categorized as follows:

1) Full immersion, full-time project-based learning
2) A project based curriculum that includes at least one large project every study year
3) Projects running along other study modules (half-day, one day/ week)

4) Capstone design courses & projects that take place at the end of studies

The categories 3 and 4 are very common all over engineering institutions. As individual courses are abundantly reported in the literature, we just refer to Chen et al [1] and other sources for more detailed accounts and discussions on findings. Categories 1 and 2 are further described below.

3.2 Summary of curriculum level implementations

Even though Maastricht University in Netherlands is not in engineering education (it offers Data science and knowledge engineering & Business engineering), it deserves to be mentioned because of its influence to other universities in Europe. It has applied problem-based learning since 1974, later enhancing and developing the education in some programmes with project-based learning and other student-cantered methods. [2]

Full immersion, full-time projects during the entire curriculum, in at least one faculty, are given in the following institutions: in Denmark Aalborg University, and DTU in Copenhagen [12]; in Finland Metropolia University of Applied Sciences, Lapland University of Applied Sciences; in Netherlands Twente University and Amsterdam University of Applied Sciences. [13] [14]

In the case of Metropolia UAS in Finland, the transition to a full-time project-learning curriculum was implemented in 2014. In engineering departments, a large number of smaller study units were combined into four modules for each study year. These 15 ECTS modules take 8 weeks, and each incorporates theoretical as well as practical subjects, most of which were included in the module project. Because all departments and programmes had freedom to plan their modules independently, the practical implementations varied widely. In some programs, teachers embraced the possibility to get involved in team teaching and project facilitation, whereas in some others they kept a more conventional approach with lectures and individual laboratory exercises with small projects. Nevertheless, the amount of project and team work for students multiplied with promising results, causing a significant increase in accumulated study credits. [15] [16]

3.3 The universities with yearly projects

Project-based curriculum in some kind of form that includes several integrating projects is implemented for instance at University College London, at Aston University, Birmingham, in the UK, and LINEACT, CESI in France. They are also members of the CDIO consortium universities where at least three project courses are included in the curriculum. Members include 75 universities in Europe, around 50 in Asia-Pacific, 19 in North America and several in Latin America and Africa as of March 2020. The member list includes many universities in Sweden, Finland, Russia, Netherlands, Denmark, UK, and Ireland. There are a couple members in France, Spain, Portugal, and Italy; however, Germany and Austria are completely missing. Presumaby, that does not indicate total lack of project-based learning in those countries; rather, it may be a language-area issue. (http://cdio.org)

The review by Chen et al [1] as well as other earlier reviews cited here report only journal articles in English. Therefore, studies that have been published in other languages (French, German, Spanish, Italian, Russian or smaller languages) remain non-reported. Nevertheless, based on our experiences in European countries, it is not probable that any significant, large-scale implementation of project-based learning would go unnoticed, rather, it is a question of different teaching traditions.

4 DISCUSSION

As described above, the two major initiatives on project-based learning, CDIO and the Aalborg model, have produced substantial literature that reports the achievements and challenges of their approach. The models have been developed with a systematic follow-up and evaluation. They have been able to show benefits in terms of student retention and motivation. The universities that have reported various kinds of implementations, in particular types 1 and 2 where projects are regular and all students conduct several projects during their studies, have reported successful results. Improved motivation, student commitment and higher professional skills are typical outcomes. Many of these universities are considered among most appreciated in their countries [14]. As they continue the project mode of teaching, they obviously find it rewarding. In case of Metropolia UAS in Finland, the collection of feedback and results has been systematic over six years [15].However, even with this one university case, the implementation of the model has taken many forms in various programs, all implementations being not comparable.

When the faculty members have acquired sufficient level of knowledge and skill in supervising and instruction, the results have obviously improved. Therefore, the CDIO consortium has built a development path for newcomers who join the effort and start reshaping their curricula. It gives guidance for staff development, and outlines phases of implementation (http://cdio.org).

In addition to the above-mentioned, well-documented models, numerous case studies have been published over the years in professional journals and conference proceedings. A meta-analysis of these case studies would be rather challenging for various reasons. Firstly, it is not known what the sample represents: is it a balanced collection of experiments or does it represent successful cases that were felt worth of publishing and leaving the failures out? This positive case bias is a recognized phenomenon in science publishing. Another serious challenge is the lack of standard in reporting. Certain settings of trials usually are included in the papers such as the composition of student groups, the location of the project in the curriculum and the contents of the implementation. However, some other questions are less frequently reported such as the experience and training of the instructors, or a comparison with other implementations or cases. [1]

Chen et al [1] summarize positive and negative outcomes of project courses, as well as problems that have been experienced. They have classified the papers in various ways. There are apparent difficulties in assessing individual case studies: firstly, they do not follow any kind of established standard, and tend to report results without systematic comparison to other cases. Often, the cases are not repeated in

successive years, or they are repeated in a modified format. On the other hand, the background of staff professional capacities, as well as student experiences, might be insufficiently described in the papers.

Issues discussed in project course evaluations usually include the types of project assignments: whether they are problems given by teachers, results of student idea generation or industry or community problems with real clients. These depend much on the motivation for the project course as discussed in chapter 2.1.

Project work and team work regularly encounter problems such as the organization and support of the collaborative effort, and the evaluation of teams. These difficulties tend to be satisfactorily solved in well-established project work settings and with experienced academic staff. Similarly, the concerns of instructor workload in a new kind of curriculum decline with accumulating experience. [16]

The question of student learning and do they achieve the same skill level or possibly better competences than with more traditional and individual learning methods is crucial. Several reports such as the survey among Birmingham graduates among others support this view [17].

5 SUMMARY AND CONCLUSIONS

The goal of this treatise is to clarify the picture of developments around project-based learning in technical universities in Europe. We hope that it is one step forward in understanding the manifold forms that engineering education currently takes and how wide the field is. We acknowledge that we could not fully cover existing implementations but sincerely hope that this mapping of practices will continue by the community of engineering educators, and universities can in the future develop their education based on firm evidence on benefits and challenges of different approaches.

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INTERDISCIPLINARITY IN TOMORROW'S ENGINEERING EDUCATION

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ABSTRACT

Universities are embracing 'challenge-based learning' (CBL) to engage students in contributing to real-life societal challenges. In CBL learning takes places through identification, analysis and collaborative design of sustainable and responsive solutions to these challenges. One aspect of CBL is working in interdisciplinary student-teams. Hence, implementation of Interdisciplinary Engineering Education (IEE) is sought, with the aim to train students to bring together expertise from different disciplines in a single context. To support this implementation of IEE, this paper presents a review that synthesizes IEE research with a focus on characterizing vision, teaching practices, and support. We aim to show how IEE is conceptualized, implemented and facilitated in higher engineering education at the levels of curricula and courses. Ninety-nine studies were included for analysis. Results indicate challenges in identifying clear learning goals and assessments (Vision). Furthermore, developing interdisciplinary skills, knowledge, and values needs sound pedagogy and teaming experiences that provide students with authentic ways of engaging in interdisciplinary practice (Teaching). Finally, a limited understanding exists of barriers that hinder the development of engineering programs designed to support interdisciplinarity (Support). This review contributes a level of awareness that allows teachers and educational leadership to take the next step towards interdisciplinarity in CBL.

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1 INTRODUCTION

1.1 Interdisciplinary engineering education and challenge-based learning

Today's social, economic, environmental, and medical challenges are complex, and often open ended and ill-defined [1]. These challenges go beyond the traditional image of engineers' tasks and responsibilities [2]. They call for a type of engineer who is socially connected, and who can work both within and outside the boundaries of his or her own discipline [3]. As a result, future engineers need the ability to access, understand, evaluate, synthesize, and apply perspectives and knowledge from fields other than their own. Or, at least be able to collaborate with those from other fields [4]. This ability would help engineers consider a broad range of environmental and social factors for approaching contemporary challenges [5].

One of the responses to these challenges and calls increasingly seen in higher engineering education is Challenge Based Learning (CBL) [6]. CBL is an interdisciplinary experience where learning takes place through identification, analysis, and collaborative design of a sustainable and responsive solution to a sociotechnical problem of which both the problem and outcomes are open [7]. CBL at least involves (1) open ended problems from real world practice that require working in interdisciplinary teams, (2) entrepreneurial acting and design thinking, (3) combining disciplines, and (4) linking curricular and extracurricular activities [7]. CBL both deepens disciplinary knowledge and stimulates 21st century skills such as self-awareness, self-leadership, teamwork, and an entrepreneurial mindset [8][7].

In our view CBL is an educational evolution, rather than a revolution, with working in interdisciplinary student-teams as a central characteristic. Hence, implementation of interdisciplinarity in engineering education is looked for, with the aim to train students to bring together expertise from different disciplines in the context of solving sociotechnical problems. The working definition for interdisciplinarity in education that studies of Interdisciplinary Engineering Education (IEE) seem to agree on is that interaction between fields of expertise requires some level of integration between those fields to count as "interdisciplinary" [9]. Interdisciplinary interactions can be considered as attempts to address societal challenges by integrating heterogeneous knowledge bases and knowledge-making practices, whether these are gathered under the institutional cover of a discipline or not. Individuals in interdisciplinary teams learn from others' perspectives and produce work in an integrative process that would not have been possible in a mono-disciplinary setting [10].

This implementation of IEE makes it timely and relevant to explore how aspects of CBL can be found in studies of engineering education. The aim is an evidence-based grounding for developing CBL in engineering education, which would allow teachers and educational leadership to take the next step towards a more systematic less diffuse approach to interdisciplinarity and CBL.

This review builds on an earlier literature review of interdisciplinarity in engineering education [11]. Because of our aim of offering an evidence-based grounding for interdisciplinarity in CBL, for this paper we provide a secondary analysis of review results, filtering for CBL-relevant findings. As such, the added value of this review consists of bringing together approaches, reported success factors and challenges from individual case studies, that can serve as points of attention for teachers, curriculum designers, and researchers of IEE, and CBL in particular.

1.2 Characteristics of CBL

To characterize CBL, Malmqvist et al. [7] make a distinction between traditional engineering education, CDIO/Problem Based Learning (PBL), and CBL. This distinction leads to the following characteristics for CBL:

- Combination of engineering and entrepreneurship/business
- Emphasis on social context
- Combination of problem formulating and designing
- Combination of team and individual
- Value-driven, with a focus on transformation and integration, and short-term and long-term value creation [12]
- Competences in sustainability problem-solving; systems thinking, and anticipatory, normative, strategic, and interpersonal competence, and critical thinking [13]
- Based on a rigorous treatment of engineering fundamentals. Students accomplish high levels of specialized knowledge in their field of study

These characteristics together form an educational vision on CBL. Or, in other words, CBL in our view is an educational concept, rather than an educational method. However, this concept asks for a translation to practice to help curriculum designers or teachers in developing their courses and teaching, and formulating support requests.

1.3 Vision, teaching, and support

To explore interdisciplinary courses and curricula we identify educational processes at three levels: *vision, teaching,* and *support* [14]. The boundaries of our review are defined by a focus on teaching and learning, with connections to the other two process layers.

Vision serves as a foundation for an interdisciplinary approach by describing the basic motivations and goals that are to govern an educational program. The primary processes, which we labelled *'Teaching'*, consist of instruction and curricular aspects such as learning goals, competence indicators, content, structure, and design of instruction, assignments and assessment, student characteristics, and teacher characteristics. *Teaching* puts the governing vision into action. *Support* consists of aspects such as infrastructure and institutional support, including available instruction rooms and laboratories, learning management systems and other tools

and techniques, practice-based management, resources for developing teacher skills, incentives, and allocated time for curriculum development.

1.4 Research questions

Little is known about characteristics that really enable CBL-activities to succeed. Additionally, as challenges are inherently unpredictable, dealing with 'emerging outcomes' is an assessment challenge in itself. This paper presents a review that synthesizes IEE research with a focus on evidence for CBL characteristics that allow educators to translate visions into effective means of teaching and support. This aim leads to two research questions:
What aspects of Vision, Teaching, and Support have emerged as topics of interest for CBL in empirical studies of IEE?
What points of attention regarding Vision, Teaching, and Support can be identified in empirical studies of IEE as supporting or challenging interdisciplinarity in CBL?

2 METHODOLOGY

To find examples of interdisciplinarity in engineering education and empirical evidence on whether the suggested IEE approach worked, we followed a pre-defined procedure [15] emphasizing the following steps: Formulation of research questions, searching for and screening of studies according to inclusion/exclusion criteria, description of study characteristics, appraisal, and synthesis of results. In this study, the approach chosen was an aggregative synthesis of results [16]. For a detailed description of the applied method, we refer to [11].

During the first step, searching for studies, target articles were identified through the Web of Science and Scopus databases. Queries were performed with the search terms "interdisciplinary" OR "multidisciplinary" OR "transdisciplinary" AND "engineering education."

Step 2 consisted of surface level screening by reading titles and abstracts and aimed to identify only relevant articles that met the following criteria for inclusion:

1. The article investigated curriculum or course-related aspects of IEE
2. Interdisciplinarity in engineering education needed to be central to the case and/or argumentation; both interactions between engineering fields, and between engineering and other scientific fields were considered
3. Participants were students or teachers in higher education
4. The article discussed at least one of the three levels of vision, teaching, support, or elements thereof
5. The article was published in an international peer-reviewed journal
6. The article was published between 2005 and 2016
7. The article was published in English and available as a full-text version

The available articles were scanned in step 3, after which a further selection was made based on criteria including the search terms discussed above. Ultimately, a

total of 99 studies were included in the review. Each of these 99 studies were coded based on a coding table. A priori codes were used to categorize the articles after reading the full text. This coding table structured the criteria for inclusion and subsequent data extraction from the included articles. The coding table included the following sections:

- General information: authors, title, publication source, publication year, abstract, keywords,
- Research design and population: qualitative or quantitative method, number of participants, main academic discipline involved,
- Vision: motivation for IEE, curriculum goals, orientation (e.g., design/research/problem-based), multi-, inter-, or transdisciplinary, system approach, discipline/field,
- Teaching: learning goals, group size, learning environment, scaffolding structures, student skills, assessment, collaboration,
- Support: organization, teacher support, barriers,
- Overall results: findings related to any of the sub-questions defined for this review.

Because of the purpose of translating the educational concept of CBL to educational practice with a focus on interdisciplinarity, the results were analysed from the perspective of CBL characteristics. Therefore, no new codes were added to the coding table as designed in [11]. To increase the reliability of this literature review, the authors collaborated closely in the process of identifying emerging themes.

3 RESULTS

3.1 Emerging themes for IEE vision

Systems approach: Many articles in our review drew upon a “systems approach” to structure IEE. In this context, a system is perceived as a collection of components undergoing dynamic interaction with one another, often across disciplinary domains, and a system approach as the required set of skills needed to handle such systems [17]. Such skills include metacognitive abilities such as systems-thinking and T-shape competencies, in which a core strength of disciplinary expertise (the vertical axis of the ‘T’) is coupled with the ability to value and work with a broad range of people and situations (the horizontal axis of the ‘T’) [18]. Systems thinking and T-shape competencies thus refer to the CBL characteristics ‘Competences in sustainability problem-solving’ and ‘rigorous treatment of engineering fundamentals’ [7].

Most of the articles investigating systems thinking explicitly advocated that instruction should start by training knowledge of a single discipline. The horizontal axis of the T-shape was subsequently described as a capstone or a combination of knowledge from different disciplines or systems, or as a combination of professional skills, such as communication, project management, presentations, or the understanding of cultural differences.

Complex real-world problem-solving: The central reported motivation behind interdisciplinarity in engineering education in the included articles is that engineers are not yet being trained well to address complex real-world problems, which require interactions across disciplinary boundaries [19].

Entrepreneurial competencies: Today's economic pressure on engineers to be entrepreneurial motivated authors to stress the value of interdisciplinary team projects for better preparing engineering students to work in industry [20] or even for learning to start their own business [21]. This motivation appears to be guided by ideas about what future workplaces will look like and what industry demands from its employees [22][23].

Socially aware engineers: Articles that focus less specifically on industry engagement and collaboration, often cite an imperative to produce engineers capable of shaping their professional work. For instance, articles with sustainability as a motivating factor [24][25], concluded that interdisciplinary engineers need to be capable of handling and integrating environmental, social and economic objectives into their work through engagement with social scientists or societal groups outside academia [26]. Authors motivated by ecological sustainability stressed the need for awareness amongst engineers of social, political, economic, and environmental constraints [24][27]. They emphasized that IEE should promote this awareness through real-world problem-solving scenarios and experiences, instead of through disciplinary learning alone [28].

Improving disciplinary competences: Internal disciplinary benefits of interdisciplinarity were sometimes prioritized in articles that spell out such benefits in terms of disciplinary knowledge and understanding, creativity or adaptability [29][30]. Because creativity and adaptability relate to skills such as project management, or working in teams, from this point of view, included studies rationalize interdisciplinarity as a useful source for training relevant professional skills [31][32][33].

These emerging themes show a natural development from traditional engineering education towards characteristics of CBL. However, where CBL emphasizes the combination of both entrepreneurship and social awareness, the included studies appeared to focus on these characteristics independently.

3.2 Emerging themes for IEE teaching

Student participation and group composition: In 16 articles IEE was organized within a single discipline by bringing in materials from other fields, for instance by bringing sustainability to a chemical engineering program [34]. This disciplinary approach is reported to force students to consider multiple perspectives, while a multidisciplinary teacher team supervises the course. Other programs (n = 37)

organized interdisciplinary education by having students from different (engineering) disciplines in one course [27][22][35][36]. Learning to work with specialists from other fields and learning to know and appreciate methods and vocabulary from these fields is thus included in the learning goals of these courses.

Pedagogies and scaffolding: Problem-Based Learning (PBL) and Project-Based Learning (PjBL) are the most often applied educational formats in IEE settings in the included studies. PBL aims to cover relevant content and procedures through careful selection of authentic problems that student teams have to study through an enquiry process [37]. In PjBL student teams are offered open and ill-defined real-world challenges and problems [25]. Our results thus suggest that PjBL reflects some characteristics of CBL, however, scaffolding students in both problem formulating and design should be included as well [7].

Assessment characteristics and procedures: Included studies suggest that assignments for interdisciplinary education need careful construction, balancing all involved disciplines and offering tasks that allow active engagement of all team members [24]. Assessment in general is considered under-developed and under-discussed in interdisciplinary educational contexts [38][39]. Despite some attention to measuring levels of integration in student knowledge [40], or for assessment regimes [22][41], our set of articles, and the extent to which they tackled assessment, raised specific supporting aspects and challenges with respect to handling assessment in IEE (see next sections, especially section 3.4).

3.3 Emerging themes for IEE support

Teacher Support: Providing instructors with the right type of training and advice for preparing and educating students of interdisciplinary work appeared a large concern in the included studies [42]. This included training teachers in the use of non-traditional or research-level problems [43], or in concepts of interdisciplinarity [42], or showing teachers how to structure their role as supervisors to be able to provide timely interaction with students during open-ended problem-solving [1].

Strategies for enhancing interfaculty relationships to support interdisciplinary education were often discussed in the included studies [44]. These strategies were reported to include creating the right external links to business partners, and internal links amongst different university programs to generate viable interdisciplinary entrepreneurship programs [45]. Some authors discussed support in terms of availability of laboratories [46] or a dynamic infrastructure or classroom design [47][48], as a prerequisite for IEE.

Institutional Barriers: Teachers who lack interdisciplinary experience themselves, may also lack enthusiasm or willingness to invest in the development of interdisciplinary programs, often due to poor institutional incentives and rewards for engaging in it [42]. Nonetheless, some included studies suggested that teachers

need more institutional training and support to play a role in their student's professional skills development [49] and interdisciplinary training [42].

Student support: Student support to communicate, integrate disciplines and utilize peer-related skills can include the use of evidence-based group structures that best facilitate interdisciplinary teamwork, including smaller teams or allowing students to self-select [20]. Students in interdisciplinary contexts are reported to have explicitly asked for access to asked for access to experts, stakeholders and relevant resources [47][50].

3.4 Supporting and challenging factors for interdisciplinarity in CBL

Supporting factors: Concepts and theory related to a *systems approach* provide a set of resources to help conceptualize interdisciplinarity in more concrete terms. Such an approach integrates content-based teaching methods with projects and problems [31][46], and thus provides specific guidance knowledge and skill requirements, and learning goals, for IEE. Further, involving *engineering professionals* [19] can play a strong role in identifying the skills that are relevant for today's engineers.

The use of *interdisciplinary, real-world problems* as a hook for projects was reported to increase student motivation [25]. Students thus also learn to understand decision-making processes, and the ambiguity and lack of information that can attend real projects. Related IEE supporting factors included *role-based learning* within student teams [51], and the importance for students to have a *good understanding of content* required to handle their project topic [52]. This relates directly to [7], who call for a rigorous treatment of engineering fundamentals in CBL. One often identified point of attention was the importance of having students learn about the other disciplines involved in the course and having them learn to *respect these disciplines* [53].

To avoid overly difficult problem tasks, research suggests that courses and projects should provide structures that *scaffold students toward success* [20]. Scaffolding structures include problems structured around goals that are achievable in one term, and assignments defined according to levels of difficulty, with learning goals related to those levels [52].

Challenging factors: *Institutional barriers*, such as the disciplinary departmental structure of colleges and universities, are reported to appear particularly resistant to interdisciplinary programs [53]. Without shared notions of interdisciplinarity, engineers will usually find it easier to avoid crossing institutional boundaries, and confronting institutional conflicts, such as scheduling and time-frame conflicts, by sticking to a largely mono-disciplinary program [22].

Furthermore, specifications of skills, such as communication and teamwork, reported in the included articles, often appear vague: "ability to list, give and receive

feedback" or "acquire language skills to move comfortably across disciplinary boundaries" [40]. This is a challenge for the CBL-characteristic 'competence in sustainability problem solving'. *Vague conceptualizations* from vision to teaching can thus lead to unclear learning goals, making it also difficult to translate these into concrete assessments that measure what they are supposed to.

With respect to teaching, a possible underestimation by curriculum designers of the level of support students need in interdisciplinary contexts might be a challenge [41]. The project management and teamwork required for modern professional contexts need *targeted instructional intervention and support* based on effective group coordination models that help students to structure and manage their teams [33].

Open-ended problems might be thought to encourage interdisciplinary interaction and flexible thinking. However [1] report that students, when asked, preferred a *scenario with more detail and clearer signposts* on what was required for a result that would be advanced enough for their educational level. Learning how to cope with the challenge of interdisciplinary work can be accomplished by starting with less open-ended, more structured problems, while working towards open-ended and ill-defined projects (ibid.).

Institutional practices and standards tend to hinder IEE, because funding, tenure and review processes are oriented along disciplinary lines [53][54]. In this context, the 'siloed nature' of academia was mentioned, in several different wordings [53][40]. Apart from the availability of laboratories and related infrastructure [46], these results suggest teachers do need institutional support to collaborate on course building. Hence there is a reported overall need for educational management to cultivate the trait of interdisciplinarity as a legitimate institutional identity and goal [53].

In essence, these challenges represent a tension between the rigorous treatment of discipline fundamentals and competences in broader and professional skills such as sustainability problem-solving, systems thinking, and anticipatory, normative, strategic and interpersonal competence and critical thinking.

4 CONCLUSION

This review applied a conceptual framework of vision, teaching and support, to synthesize and categorize current results and emerging themes in IEE. Vision, teaching and support aspects are interrelated, because vision (the 'why') needs to be translated into teaching ('how' and 'what'), which in turn requires support. Conversely, teaching should aim to meet a guiding vision, and support should be applied to remove barriers for students and teachers. Our work in this review intended to support or facilitate practice related to interdisciplinarity in CBL by collecting and organizing current results in this way.

Limitations to this study concern uncertainty about the generalizability of included case results. Many of the results were often derived from only a few studies based on specific cases. Further, this uncertainty is caused by a lack of conceptual consistency across studies. We have avoided for the most part drawing generalizations about what may or may not work extensively across all IEE contexts in favor of these reporting findings as individual results, and we would caution against applying these results without due attention to the details of the case reported. A further limitation likely arises from the search terms used to identify studies. Our focus on inter-, multi-, and transdisciplinary work left out possibly relevant work using “cross-disciplinarity” or “cross-disciplinary” as its central terms for interdisciplinary interaction. Finally, the inclusion criteria of full-text available studies might have caused a bias in our results.

Evident from this review is that both teachers and students need support and scaffolding to address real-world sociotechnical problems of which both the problem and outcomes are open. The CBL-characteristics as reported by [7] all appear with evidence for educational practice, apart from ‘value-driven’. This should be seen as a call for curriculum designers to make sure that CBL-assignments include attention for transformative and integrative values, and short-term and long-term value creation [12]. Furthermore, the tension between ‘sustainability problem-solving competences’ and ‘rigorous treatment of engineering fundamentals’ is apparent because there was no prevalence for either of these characteristics. This relates to two frequently found lines of thinking found in the literature regarding what students should learn first: single discipline knowledge [55] or broader skills [20]. By referring to constructivist theories, the single discipline approach argues that students need to develop in-depth knowledge of their chosen discipline first before they can construct knowledge together with others. The other approach prefers a broad overview of the field before students can understand the depth of their specific field. A third, less often encountered approach starts with a whole-systems design and subsequently works in iterative cycles going between disciplinary and broad learning [32][56].

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HOW DOES EER CONCEPTUALIZE ITS OBJECT OF STUDY? – AN EXPLORATION BASED ON THE "DIDAKTIK TRIANGLE"

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ABSTRACT

The Engineering Education Research (EER) community in Europe and across the globe has grown considerably in the past decades. There have been some examinations to date of the research corpus that has evolved, although these have been predominantly US-based. An emerging literature has started to chart the ways in which European EER-researchers have a distinctive tradition, which might at least in part be due to the influence of the European "Didaktik" tradition, which conceptualizes teaching and learning as fundamentally resting on an interplay between student, teacher, and the content (subject matter). This is represented in the "Didaktik triangle" where student, teacher, and the content are placed on the vertices of the triangle, and the sides of the triangle represent three important interrelations. This study compares the 50 most highly cited papers in each of the European Journal of Engineering Education (EJEE) and the US-based Journal of Engineering Education (JEE). Our analysis of how the topic(s) of the papers related to the "Didaktik triangle" shows that the conceptualization of the object of study in the EJEE papers was more related to the "Didaktik triangle" as a whole compared with papers published in JEE. The results of our study provide further evidence that there are, indeed, some differences in the aims of American and European EER. A global community would do well to try to draw on the strengths of both of these traditions.

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1 INTRODUCTION

1.1 European Didaktik tradition

It has been suggested that educational thinking and research in continental and northern Europe is strongly influenced by the *Didaktik*[2] *tradition* [1, 2] with roots in the thinking of scholars like Johann Amos Comenius [3] and Johann Friedrich Herbart [4].

Didaktik can be defined as the science of teaching and learning. Künzli [5] summarizes the central questions of Didaktik into:

- What is to be taught and learned (i.e., the content aspect).
- How is "content" to be taught and learned? (i.e., the mediation or method aspect).
- Why is "content" to be taught and learned? (i.e., the goal aspect).

In the Didaktik tradition prominent emphases is given to content and goals – this means that the *what*- and the *why*-questions are are indeed central considerations to be problematized and studied [2]. As succinctly expressed by Künzli [5] the "fundamental question of Didaktik is *Why is the student to learn the material in the first place?*" (italics in original). In the Anglo-Saxon curriculum-studies-tradition the *how*-question is seen as the core question while, typically, the content is more or less assumed as given and accordingly the *what*- and the *why*-questions are downplayed [2].

Borrego and Bernhard [6] offer one of the first studies in the literature that survey the EER field and contrast US and European approaches. They suggest that EER in Europe is mainly situated in the "Didaktik tradition" while EER in the US is more influenced by the "Curriculum-studies-tradition". Thus, in Europe, deliberations regarding what should be learned and why it should be learned are seen as valid objects of study and are more in focus than in the US. Furthermore, they argue that in Europe EER research is to a higher degree problem-led (i.e. a focus on the problem investigated and the insights generated) while research in the US to a higher degree has been method-led (i.e. a focus on proper use of methodology and "rigorous" research).

Some further indication of how these differences in traditions play out in contemporary EER can be noted in the descriptions of the PhD-programmes in engineering education research at Purdue University, USA, and at Linköping University, Sweden, that both were initiated in 2004. According to Purdue's description they "established … engineering education doctoral program [in 2004], for students who wish to pursue rigorous research in *how* engineering is best taught, learned, and practiced" (our italics) while Linköping University presented the following description: "The subject of engineering education [Ingenjörsvetenskapens Didaktik] deals with learning, teaching and the formation of knowledge in the art and science of engineering in a broad sense. In focus stand fields of *knowledge of*

[2] The spelling, 'Didaktik' is deliberately used to distinguish the European 'Didaktik tradition' from the English term 'didactics,' which has a different meaning.

relevance for the practice of, and education for, the engineering profession and its relation to the advance of knowledge in techniques and technology. …" [7, our translation]. Linköping University's description also specifically mentions "selection of content" (ibid.) among other things. Thus, as demonstrated here a focus on the *what*, *how* and *why* can be seen in Linköping's description, while a strong focus on the *how*-question and on "rigorous research" is prominent in Purdue's description.

1.2 Didaktik triangle

A central tenet in the *Didaktik tradition* is that organized teaching should be seen as an active and dynamic triadic relationship (see Fig. 1) – the *Didaktik triangle* – between three elements: *Subject matter (content)*, *student*, and the *teacher* [e.g. 3, 4, 5].

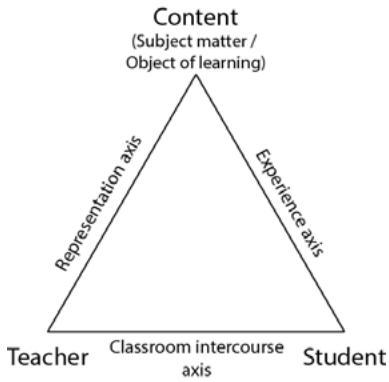

Fig. 1. Didaktik triangle [5]

As can be seen in figure 1, *Teacher*, *Student* (learner), and *Content* (subject matter, object of learning) form the vertices of a triangle in this conceptualization of teaching and learning in a learning environment. The vertices are joined by the *Classroom intercourse axis* joining Teacher – Student, by the *Experience axis* joining Student – Content, and the *Representation axis* joining Content – Teacher. Within this model it is possible to lay different emphasis on different elements of the triangle or treat the elements in different ways. For example the Experience axis can be viewed in an "objective" way, i.e. in which ways the Student(s) is supposed to experience Content, or in a "subjective", i.e. in which ways the Student(s) actually experience Content [5].

There exist many extensions to the Didaktik triangle. For example, Novak and Gowin [8] added Evaluation and Context (i.e. five vertices), Sträßer [9] added Artifacts used in teaching and learning and constructed a tetrahedron (i.e. four vertices), and Rezat and Sträßer [10] related the Didaktik triangle and the tetrahedron to Engeström's elaborate activity system [11]. Kansanen and Meri [12] on the other hand argue for retaining the basic Didaktik triangle, but suggest that although the Didaktik triangle should be treated as a whole it is almost impossible to do so in practice. Thus, they claim, a productive approach to analysis is to focus on each pair (i.e. what are named axes above). The Teacher – Student pair (i.e. Classroom intercourse axis) he puts forward as the "pedagogical relation". Furthermore, in his model, he added a "Didaktik relation" that is conceptualized as an arrow going from the Teacher affecting the Student – Content pair (i.e. Experience axis).

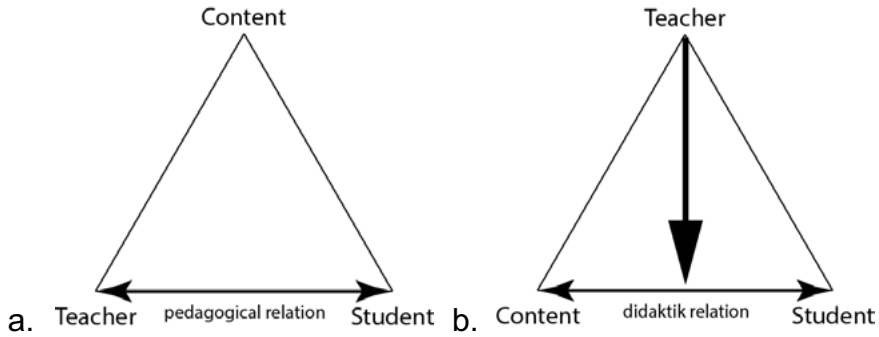

Fig. 2. a) Illustration of the “pedagogical relation” (to the left), and b) the “Didaktik relation” (to the right) according to Kansanen and Meri [12].

The Didaktik triangle can also be used to conceptualize aspects of the teaching and learning situation. Marton and co-workers [e.g. 13] distinguish between the *intended object of learning*, the *enacted object of learning* and the *lived object of learning*. The intended object of learning consists of the subject matter and the skills that the teacher or curriculum planner is expecting the students to learn and this would relate to the teachers view on Content, i.e. representation axis as indicated in fig. 3a. The enacted object is what it is actually made possible for the student to learn by the design of the learning environment and would correspond to the teachers enactment of the Representation and Classroom intercourse axes, while monitoring students’ experience as is indicated in fig. 3b. This mean that our view is slightly different from the view of Kansanen and Meri [12] presented in fig 2b. Finally, the lived object of learning is the way students see, understand, and make sense of the object of learning and the relevant capabilities that the students develop that would correspond to the Experience axis as indicated in fig. 3c.

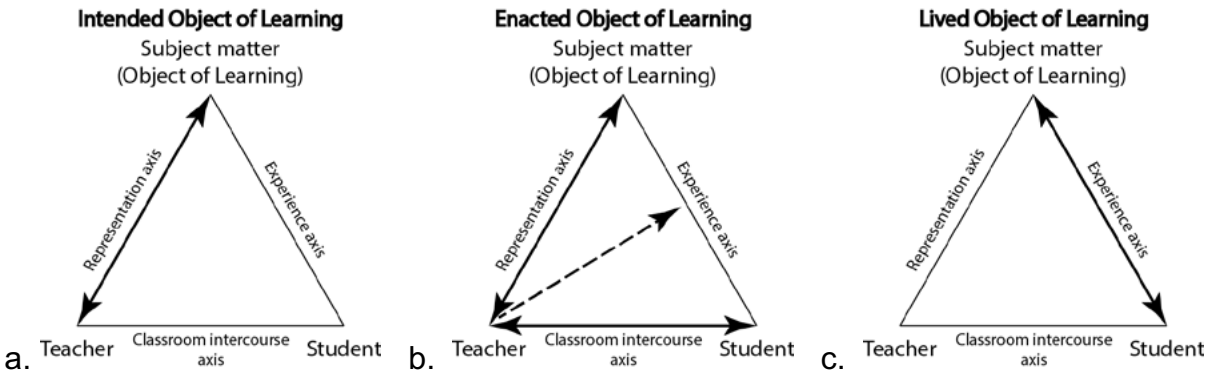

Fig. 3. Conceptualization of a) intended, b) enacted, and c) lived object of learning [13] in relation to the Didaktik triangle

Although the model of the Didaktik triangle simplify what occurs within an engineering learning environment, in our view, it serves as a simple, but yet powerful enough, starting point to theorize the dynamics of teaching and learning, as well as contextualizing and situating the elements in relation to the each others. Thus, the aim of this study is investigate to what degree the elements of the Didaktik triangle can be identified in EER journal papers.

1.3 Previous investigations

Over the last period there has emerged a substantial literature looking at the theory and methods that are being used in EER. Much of this work has proceeded through bibliometric analyses of published articles, including investigations of author origins, citations, and the like (for example Williams, et al. [14] and Wankat, et al. [15]). But from early on there has also been deliberation in more detail on how EER researchers are approaching their research. Wankat [16] notes that while the JEE was starting to publish more articles with a research orientation, that there was still a very low level of use of educational theory in these. Koro-Ljungberg and Douglas [17] survey the emerging use of qualitative methodologies in EER and this is further expanded on by Case and Light [18]. Malmi, et al. [19] do a useful survey of EJEE articles to complement this literature which had hitherto tended to be quite US-focused. They show that while EJEE authors do show use of educational theory, this tends to be limited to a pretty narrow set of explanatory frameworks.

To our knowledge, the only investigation of EER using the Didaktik triangle as an analytical tool is the work by Kinnunen and Malmi [20]. They have investigated the papers presented in the EER-track at the SEFI annual conferences in 2010 and 2011. They further extended the Didaktik triangle of Kansanen and Meri [12] ending up with 13 categories and also applied a multi-layered Didaktik structure consisting of three layers; Teachers, Organization, and Society. Thus they ended up with 39 categories in their analysis making their results somewhat difficult to compare with the analysis we have done (See section 2 below). Furthermore they have only analysed a conference situated in Europe while we are comparing journals based in Europe and the US.

2 METHODOLOGY

Two of the leading scholarly journals in the field of EER are the Journal of Engineering Education (JEE) owned by American Society for Engineering Education (ASEE) and the European Journal of Engineering Education (EJEE) owned by European Society for Engineering Education (SEFI). Although both journals aim for an international readership and accept papers internationally we suggest that an analysis of publications in these journals can reveal differences in research traditions between the US and Europe as the authors published in EJEE are predominantly from Europe and the authors that get published in JEE are predominantly from the US.

In this study we used the Scopus database to retrieve the 50 most cited (according to Scopus) papers published between 2008 and May 2019 in JEE and EJEE respectively. The year 2008 was chosen as it was the year that SEFI's working group for Engineering Education Research was established. As in some instances citation rankings were shared, we ended up with 53 papers from EJEE and 51 papers from JEE.

In this study we aimed to develop an analytical tool based on the Didaktik triangle for analysing papers with some kind of empirical investigation of teaching and/or learning in university level engineering education. Papers that were out of scope for such an analysis – for example review papers, papers discussing the EER-field or methodology, or papers related to school level engineering education – were excluded from the analysis. Twelve papers were excluded for EJEE resulting in 41 papers being analysed, while for JEE 22 papers were excluded resulting in 29 papers being analysed.

3 RESULTS

In this preliminary analysis we used six non-exclusive categories related to the vertices and the axis of the Didaktik triangle. The characteristics that we used for assigning a paper to one or more of these categories is shown in the table below. For each category we refer to one paper that exemplifies this approach. For the first three categories, these are papers that we judged to have a predominant emphasis on one vertex of the triangle. The following three categories are papers where our analysis identifies a focus on one of the axes (the pairs). The final category refers to papers which we judged to represent all the dimensions of the triangle.

Table 1. Categories used in the analysis with examples of a paper classified to each category

Category	Characteristics of the category
Teacher	The teacher(s) and some characteristics of the teacher(s) is/are apparently visible in the paper. *Example: Borrego, M., Froyd, J. E., & Hall, T. S. (2010). Diffusion of Engineering Education Innovations: A Survey of Awareness and Adoption Rates in U.S. Engineering Departments. Journal of Engineering Education, 99(3), 185-207.* This study asked engineering department chairs in the US about their awareness of some common innovations in engineering education and to what extent any of these have been implemented in the department. The department chairs are seen, in this study, as being a representative for what is happening in the department. As this study is only focusing on the department chairs' awareness and his/her knowledge of teachers' adaption of innovative curricula within the department we categorise this paper in the *teacher* category.
Student	The student(s) and some characteristics of the student(s) is/are apparently visible in the paper. *Example: Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy. Journal of Engineering Education, 98(1), 27-38.* This study sought to characterize US women engineering students' self-efficacy (i.e. a person's belief in his/her own capabilities). As neither the relation to teachers nor content is explicitly discussed we categorise this paper in the *student* category.
Content	Content (Subject matter, object of learning) – i.e. the knowledge, values, and skills students are supposed to learn – is apparently visible in the paper. *Example: Male, S. A., Bush, M. B., & Chapman, E. S. (2011). An Australian study of generic competencies required by engineers. European Journal of Engineering Education, 36(2), 151-163.* The views of established engineers on which generic competencies were seen as most important for engineering work have been studied. As this paper discusses the the knowledge and skills that are seen to important for the students to learn it is categorized as *content*.

Table 1. Continued

Category	Characteristics of the category
Teacher–Student (Classroom intercourse axis)	Some topic related to the Teacher–Student–relationship is apparent in the paper. Interactions with some proxy for the teacher, such as lab-instructions, are included in this category as these are designed by the teacher. *Example: Vogt, C. M. (2008). Faculty as a Critical Juncture in Student Retention and Performance in Engineering Programs. Journal of Engineering Education, 97(1), 27-36.* This paper addresses the importance of university teachers for the classroom climate and the development of students' self-efficacy, academic confidence, sound learning behaviours and performance. Thus the paper is categorized as related to the *teacher – student* relationship.
Student–Content (Experience axis)	Some topic related to the Student–Content–relationship is apparent in the paper. It could, for example, be how students have learned or experienced the content, but it could also be students' views on the content. *Example: Daly, S. R., Yilmaz, S., Christian, J. L., Seifert, C. M., & Gonzalez, R. (2012). Design Heuristics in Engineering Concept Generation. Journal of Engineering Education, 101(4), 601-629.* This paper presents a study of how engineering students and practitioners generated concepts and used a collection of design heuristics to explore design spaces. Thus *students'* (and practitioners) relation to content is explored in this paper.
Content–Teacher (Represen-tation axis)	Some topic related to the Content–Teacher–relationship is apparent in the paper. It could, for example, be the teacher's view on content, but also how the teacher represents or selects content. *Example: Ahern, A., O'Connor, T., McRuairc, G., McNamara, M., & O'Donnell, D. (2012). Critical thinking in the university curriculum – the impact on engineering education. European Journal of Engineering Education, 37(2), 125-132.* This paper investigate how teachers in different disciplines define critical thinking and how they say they teach critical thinking in their courses. Thus the paper discuss how *teachers* think about *content*.
All categories	*Example: Carstensen, A.-K., & Bernhard, J. (2009). Student learning in an electric circuit theory course: Critical aspects and task design. European Journal of Engineering Education, 34(4), 389-404.* This study is an example of design-based research where the authors, in the context of an electric circuit theory course, deal with teachers' intended objects of learning, the enacted objects of learning through the design of tasks, and students' resulting lived object of learning. Thus all categories are explored in this paper.

Figure 4. shows overall counts for the prevalence of the six categories across the papers that were analysed. A few conclusions are immediately apparent. Firstly, papers in both journals show a marked emphasis on considerations pertaining to the student. The EJEE papers show significantly more representation of matters relating to the teacher and to content, and also of the various 'pair' relations in the Didaktik triangle. These observations will be further unpacked in the section to follow.

4 DISCUSSION

This study is one of the first explorations using the Didaktik triangle as an analytical tool for investigating the topics in EER related to teaching and learning. This study demonstrates that this is a feasible method for analysing or conceptualizing EER, but

also as a potentially valuable model to be used in discussion about teaching and learning.

The results of this study further corroborates the suggestion by Borrego and Bernhard [6] that there are some differences between European and US research tradition, at least if the journals EJEE and JEE are taken as representatives for each tradition. Treatment of Content and the Teacher, and addressing the Didaktik triangle as a whole seem to be more predominant in EJEE. This is not a surprise as this corresponds to the differences seen in other areas of education [1, 2].

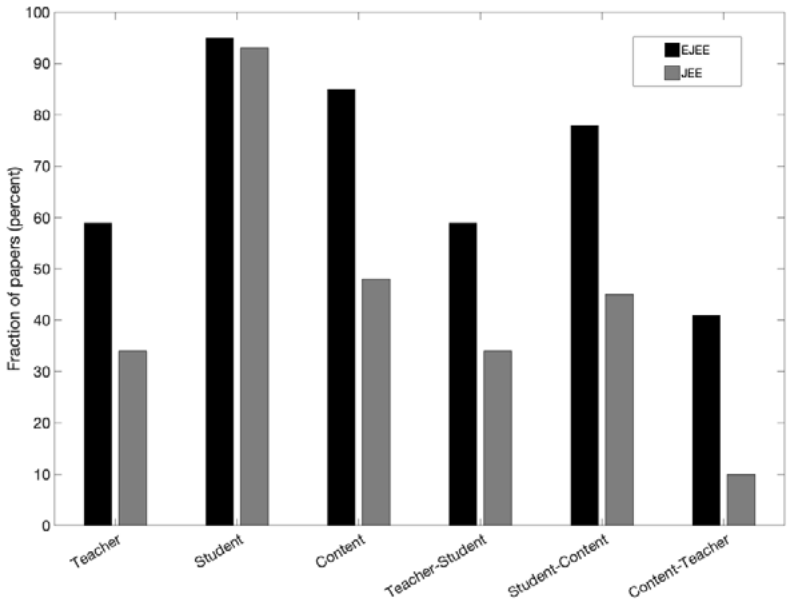

Fig. 4. Prevalence of the six different Didaktik triangle related categories in analysed papers.

The more frequent treatment of the Didaktik triangle as a whole can be taken as an indicator of more holistic thinking in Europe, but turned the other way around it could alternatively indicate that papers in EJEE are less focused than papers in JEE. Indeed Kansanen and Meri [12] pointed out that it in practice is very difficult to focus on the complete triangle. In our view being focused on one dimension of the triangle might well be a productive approach for research as long as one is aware of the fuller picture. A global EER-community would do well to understand and to try to draw on strengths of both traditions.

The Didaktik triangle can also be used in a more meta-level discussion to discuss if some topics are missing across the spectrum of EER literature. Fig. 4 shows that it is less common that EER address the Teacher or the Content vertices and it is less common to address the Teacher–Content pair. Indeed, Holmberg and Bernhard [21] used the Didaktik triangle to argue for the need to study teachers' views on content.

In conclusion then, the findings of this preliminary study suggest that further engagement with the Didaktik triangle as an analytical approach, a theoretical model, and a spur for further conversations, could be a valuable addition to the global deliberations in the field of EER.

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ENGINEERING IN DUTCH SCHOOLS: DOES IT EFFECT STUDY CHOICE?

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Keywords*: Engineering education, Study choice, Secondary schools, Gender*

ABSTRACT

Increasing visibility of STEM fields in schools is one way to increase the percentage of students opting for a STEM study. In the Netherlands there are two ways this has been implemented. Firstly, students can choose the course 'Onderzoek en Ontwerpen' (O&O; Dutch for Research and Design) which is offered in lower as well as upper level classes. Alternatively, they can choose the course Nature, Life & Technology which is only offered in upper level. O&O contains mostly engineering related subjects and NLT is a combination of science and engineering topics.

Our study shows a quantitative analysis of the study choice after school over a ten-year period of students with O&O (n=4.936) or NLT (n=27.397) comparing with the full cohort (n=331.602). We find that O&O effects study choice substantially, while the effect is less strong for NLT. Zooming in on female students, their participation in O&O (34%) and NLT (44%) at school are high compared to what we find in typical scientific engineering programs. In the 2010-2013 period we see many female O&O students opting to study Medicine, whereas the 2014-2019 period shows a substantial increase in female O&O students entering science and engineering programs.

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1 INTRODUCTION

Stimulating students to opt for a study path within the STEM fields (Science, Technology, Engineering, Mathematics) is still necessary in order to, finally, increase their participation on the labour marked in these fields. STEM related programs at secondary schools is one of the steps we can take [1]. Within this framework, up to now 95 Dutch schools (15% of all schools with A-level examinations) have implemented engineering in their schools by an extra course called Onderzoek en Ontwerpen (O&O; Dutch for Research and Design). The number of these so-called Technasia is still growing. A rerun of our analysis in 2015 [2] over a ten year period instead of five years has been conducted. It shows a consistent pattern when zooming in on the study choice at our university, with a five times higher number of O&O students in our dataset. O&O students enrol more often in Design and Construction Engineering Programs compared to regular students. This result triggered us to look at Nature Life & Technology (NLT) as well. NLT is a similar STEM related program at Dutch secondary schools. This interdisciplinary NLT subject [3] is given in addition to the regular courses in physics, mathematics, chemistry and biology at 246 (46%) schools.

Looking at our own bachelor influx, it only shows a limited picture of the study choice of both student groups. Therefore, to gain insight into whether these educational innovations really contribute to increasing the intake into technical programmes in the Netherlands, we have looked at examination cohorts over the period 2010 to 2019 across the country.

1.1 Background O&O and NLT programs

In 2004 the Technasium Foundation started a new type of school profile called Technasium. Technasium schools offer O&O from Grade 7 to 12 (age 12-18). The foundation was initiated by two parents who had more challenging STEM education in mind for their children. NLT exists from 2007 at schools and is only taught in upper secondary education, Grade 10 to 12 (age 15-18). This subject was developed as a national initiative in order to create more coherence between the individual STEM courses. Both interdisciplinary initiatives at secondary school level are a response to the need for more integrated and interdisciplinary STEM approaches. Even though they are not compulsory, a majority of the secondary schools engage in either of these two initiatives [4]. It has required large efforts at the schools in developing the new subjects, selecting or writing course materials, teacher training and communication with the world of science and technology outside the schools [2]. The quality of both subjects is supported by audits that zoom in on both the course materials and the implementation. Because these innovations have been embedded in Dutch education for (almost) 15 years, we are now able to provide a realistic picture of the effects on the STEM related study choice of students with either an O&O or NLT background.

1.2 Features of the O&O and NLT programs

Both subjects pursue similar goals and have a set-up in which different course contents and skills are combined in projects (O&O) or modules (NLT). The main goals of O&O are (1) to prepare students for studies and employment in STEM fields and (2) to encourage students to develop into competent designers or researchers. O&O is an addional subject which is scheduled 4 hours per week from grade 7 to 12. Throughout their school career students work as a team on real assignments of companies or other organisations. The O&O teacher searches for assignments at companies in the neighbourhood. The student teams than work independently using a prestructured project format and dedicated workplace facilities. Many parts of their teamwork have to be structured by the teams themselves. Their teacher has a coaching role. The final assignment, mostly in pairs, connects with a university research theme with access to some university facilities and a consultant that they can contact. The main goals of NLT are to (1) increase the attractiveness of STEM study programs and (2) to show the connections between the individual science subjects. To achieve this, the examination programme focuses on four characteristics: interdisciplinarity, study and professional context, the interaction between technology and natural science and the relationship between mathematics and natural science. NLT is scheduled 2 hours per week from grade 10 to 12, being one of the STEM options students can select in their upper secondary school profile. As with O&O, teamwork is also important in the NLT context. In addition, NLT also has an individual component because students have to do tests as well. Asking the students what they think of the subject, O&O students appreciate the freedom and independence within the subject whereas NLT students appreciate the structure and depth of NLT [5].
The subjects intend to offer attractive interactive STEM education at school and simultanously intent to increase the students interest in technique. How to explain study choice effects, if any, is complex. In literature we found among others contribution to attitude change and increasing motivation. For example, Vossen et al. [6] found that O&O students had more positive attitude towards doing research and design activities than regular students and appeared to find doing design activites more enjoyable than doing research activities. Kolmos et al. [7] found that intrinsic motivation is one of the most dominant factors to attract more engineering students. Their study concerned personal experiences and feelings in relation to engineering related activities. Furthermore, Dutch (Technical) Universities act as partners in networks with secondary schools, e.g. by supporting O&O students in their final assignments, by developing NLT modules on frontier STEM subjects and via teacher training programs.

1.3 Female students

An additional goal of the innovations at secondary schools is to raise the number of female students choosing science and enigineering career paths. In western countries it is well known that girls no longer lag behind boys when it comes to educational achievements [1]. In the Netherlands, girls attain on average a higher educational level at the end of their school career than boys even in STEM related courses if chosen.

However, in general they still do not opt that much for STEM related bachelor programs in higher education. In order to increase the STEM related workforce, we need the female students as well.
The practical experience and hands-on exercises with real-life examples in the O&O and NLT courses is very promising to change the attitude and motivation of female students as is also mentioned in the Microsoft study [8] as second and fourth important driver to sustain girls interest in STEM. Additionally, bringing girls into contact with female role models, preferably from the very young age, has proven to be effective in getting them interested in technique [9].

1.4 Research questions

Considering the promising STEM related aspects of the O&O and NLT subjects for both male and female learners, we expect higher influx numbers for STEM related studies at Dutch universities. We expect higher numbers in engineering studies for O&O students and higher numbers in science related studies for NLT students. Additionally, the courses have been offered for quite a number of years. Over the years they have been improved and adapted where necessary, giving them a permanent place in Dutch education though not at all Dutch schools. This offers us the opportunity to see variations in what studies are chosen by students from the different school types over a ten year period.

The research questions in this study are:
(1) Do O&O students opt for science and engineering studies more often than regular students? (sub-question: Do more female student select science and enigineering studies?)
(2) Do NLT students opt for science and engineering studies more often than regular students? (sub-question: Do more female students select science and engineering studies?)
(3) What are the differences (if any) between the study choice in terms of sector of interest of O&O students compared to NLT students?
(4) Have there been any changes in the study choice in terms of program choice of both O&O and NLT students in the last ten years?

2 METHODOLOGY

2.1 Data source

A large national dataset was obtained as a pivot table in Excel from Platform Talent for Technology[2]. The Platform has built up a knowledge base with anonymous data from DUO (Dienst Uitvoering Onderwijs). DUO is a Dutch governmental organization that collects data on all publicly funded education in the Netherlands. Privacy considerations are taken into account and outcomes can not be traced back to individuals.

[2] Dutch National Agency for STEM-education and Labourmarket (former STEM-Platform)

2.2 Data analysis

We consider the full cohorts 2010 to 2019 of pre-university students (VWO). The year designation means that the diploma was obtained in that year. Most students (90%) start immediately after graduating from their secondary school, 9% one year later and 1% two or more years later. In the Dutch schoolsystem O&O and NLT courses are also offered at senior general secondary education (HAVO) that prepares students for universities of applied sciences. The VWO level prepares for academic studies at technical and other research-oriented universities. In this study we only look at the transition from VWO to academic bachelor programs.
At the upper secondary school level students choose a profile. In our study, we zoom in on those students with Nature & Technology (NT) or Nature & Health (NG) profile, discarding students from other (non-STEM linked) profiles. Some Technasium schools also offer NLT. Checking the number of students who had both O&O and NLT (0,4% of all O&O students), we concluded that this will have no influence on the trends.
To distinguish between science and engineering related programs we use the sector classification used by DUO. The sectors of interest (based on highest number of enrolment) are: *Technique*, *Nature*, *Healthcare* and *Behaviour & Society*. The remaining sectors are indicated as *Other* (Economics, Agriculture, Education, Law, Language&Culture, Cross-sectoral). Because our dataset is based on population data, we are using Chi Square tests to look at differences in expectations and observations.

3 RESULTS

3.1 Population numerical data

The number of students in our study is shown in table 1. The high percentage of students with an N-profile within the O&O or NLT group is because these courses are developed for the N-profile.

Table 1. General numbers and percentages population (total cohorts 2010-2019)

	Students		N-Profiles	
Group	**Number**	**Percentage**	**number**	**% of group total**
Full population Female	331.602 176.607	53% of full population	187.898 92.241	57% of full population 52% of Female
All O&O Female O&O	4.936 1.689	1,5% of full population 34% of all O&O students	4.896 1.668	99,2% of all O&O 98,8% of Female O&O
All NLT Female NLT	27.397 12.184	8% of full population 44% of all NLT students	27.353 12.164	99,8% of all NLT 99,8% of Female NLT

3.2 Transition to university: distribution across program sectors

85% of VWO students opt for a university program. Other students opt for universities of applied sciences or do not enrol at any (funded) educational institution in the succeeding year. In figure 1 the study choice of O&O and NLT students for a university is compared to all students where the programs are categorized into sectors.
Both O&O and NLT students opt significantly (p<.001) more often for *Technique* programs compared to all students. The difference is the largest for O&O students. NLT students opt slightly more often for *Nature* oriented programs than all students. The percentage of O&O students that opt for *Nature* programs is less compared to all students. Looking at the female students we see a similar pattern, though the sum of *Technique* and *Nature* is lower than that of the average of the whole O&O group, with big gains for the healthcare sector enrolling large numbers of female students.

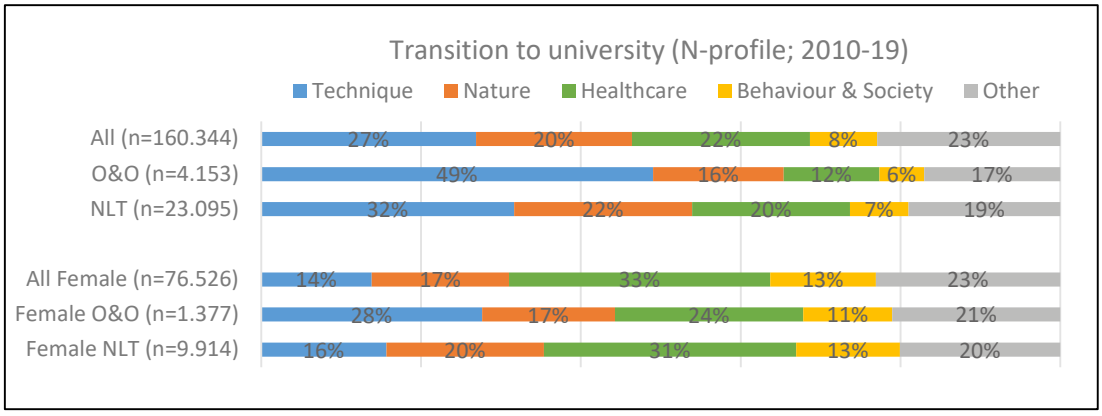

Fig. 1. Transition to university of O&O and NLT students compared to all students per program sector.

Zooming in on both female O&O and NLT students by making a long term overview, we see in figure 2 a jump to a significantly (p<.001) higher average percentage of female O&O students opting for *Technique* in the 2014-19 period compared to the beginning years 2010-13. A simultanuous drop can be seen for *Healthcare* programs, see also table 2.

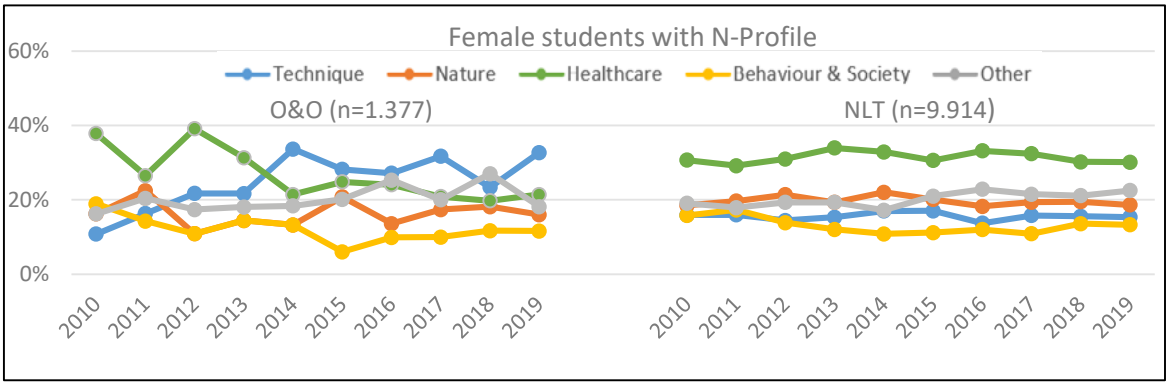

Fig. 2. Transition to university of O&O and NLT students compared to all students per program sector.

Table 2. Sector choice Female O&O students with N-profile: Difference in average percentage periodes 2010-13 and 2014-2019

Sector	Average 2010-13	Average 2014-19	Difference
Technique	18%	29%	+11%
Healthcare	34%	22%	-12%

For the female NLT students, we did not find any change at all over the whole period with a Technique preference at 16% (stdev=1,0%) and Healthcare average at 31% (stdev=1,6%). *Healthcare* programs are most favourite followed by *Nature* related programs at 20% (stdev=1,2%). The question is what's going on among the female O&O students, are many of them dropping healthcare in favour of engineering programs? In our previous study [2] we assumed that O&O girls mainly opt for medicine, therefore an interesting question is what happened since 2014?

3.3 Study choice female O&O students

Figure 3 shows the top three studies of female O&O students within the sectors *Technique* and *Healthcare* where respectively industrial design and medicine as the most favourite ones. Comparing the enrolment over time with the *Technique* and *Healthcare* line in figure 2, we see a similar pattern. The number of female O&O students opting for industrial design increases whereas the number opting for medicine decreases, making a change in preferences as likely explanation.

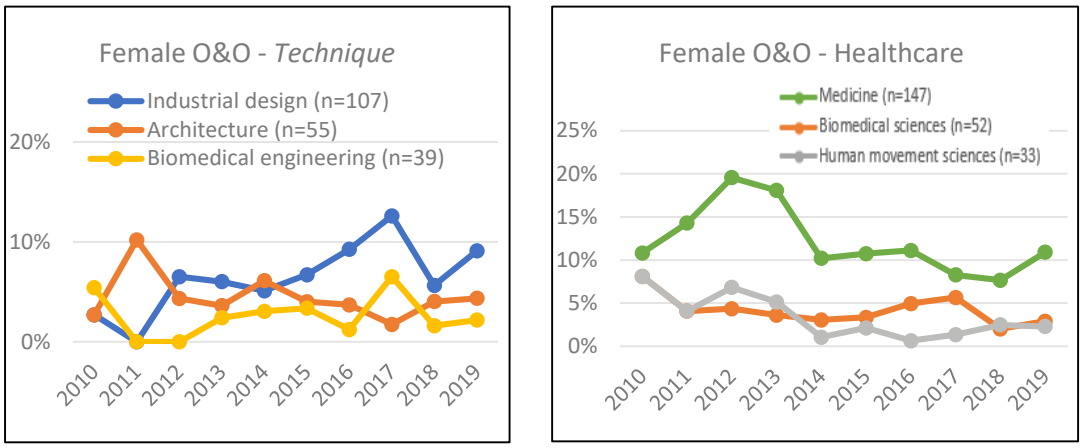

Fig. 3. Top 3 study choice within sector Technique and Healthcare for female O&O with N-profile.

As an underlying explanation we looked into regional variations. Technasium schools and nearby universities collaborate on many aspects including, orientation visits, facilitation of the final assignments of O&O students, parents might work there, and finally many school students, both male and female, will have a first look at the study programs at a nearby university. The variation in female students opting for

technique programs turns out to be substantial with the lowest score in the northern part of the Netherlands (17%) with the University of Groningen nearby, as compared to regions near one of the Technical Universities: schools near the University of Twente (28%), near Technical University of Delft (29%) and in the proximity of the Technical University of Eindhoven (41%). This underlying explanation linked to the regional educational ecosystem turns out to be a good candidate to explain the jump in female students we found since 2014, as many schools in high scoring regions (such as near Delft and Eindhoven) started their Technasium profile around 2007-2008, delivering their final year students from 2014 onwards.

4 CONCLUSIONS AND DISCUSSION

Based on full cohort data over a period of ten years we showed in this paper that the STEM related aspects of the O&O and NLT subjects both lead to higher influx in STEM related studies at Dutch universities. O&O students as well as NLT students opt for science and engineering studies more often than regular students, where we see a strong shift to *Scientific Engineering* related programs for O&O students. NLT students choose slightly more often *Nature* oriented programs. Female students show the same pattern, which means that in particular O&O at schools encourages girls to more often opt for scientific engineering programs. Furthermore, O&O starts at an earlier age compared to NLT allowing for a bigger influence on study choice, for example by building self-efficacy and confidence [6].

However, one jump in numbers does not fulfill our aim to have a more balanced gender representation in science and engineering programs in the Netherlands. The 31% female students in the Netherlands choosing such programs is still way behind the 61% of male students doing so. The same pattern can be found for students with NLT as an exam subject, 35% vs 68%, and for O&O with 44% vs 76%. We do however see that introducing STEM subjects properly can help make a difference. A more qualitative analysis of O&O project characteristics and educational practise will help us to improve our understanding of the differences among schools, while highlighting what they can do to further interest, attitude and motivation related to STEM study programs and career opportunities [7], with particular interest into the gender aspects as the growth potential is high among female students [9]. A further study about the higher percentage of female students choosing NLT than O&O (44% vs 34%, see Table 1) is worthwhile. Explanations might be sought in the admissibility and/or in the content offered. If NLT is offered at a school, all regular students with an N-profile can choose it. For O&O you have to do the Technasium stream from the 7th grade with a midterm decision at the end of the 9th grade whether to continue in the upper classes. We might loose some of the girls here. Analysing the content, overall NLT leans more towards science while O&O relates to engineering more than to science. Besides the mainly quantitative approach in this study, limitations in our study are the small numbers of O&O students in the early years, and the fact that there will be some self-selection of technique oriented children and/or parents selecting a Technasium school with O&O on offer. Looking at the future, the regional variations can be analysed in

more detail with a combination of quantitative and qualitative methods that jointly will help test more detailed explanations.

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CHOOSING CHALLENGES IN CHALLENGE-BASED COURSES

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ABSTRACT

Challenge-based learning (CBL) is increasingly on the higher education agenda. In many universities of technology in the Netherlands, CBL is being implemented in engineering education programmes to prepare students to work on authentic, complex, societal challenges, provided by partners from outside of the university. Making societal impact is an important driver the introduction of CBL, however, on a more pedagogical level, little is known about the motivational aspects of student learning in these challenge-based transdisciplinary courses.

In CBL, self-regulation has a prominent role. In many instances, students are asked to make motivated decisions about their development trajectory within the CBL process. One of the first decisions students have to make in these type of learning configurations is what challenge they will work on. The structure of CBL courses often involves several partners that all present their own challenge to the students. Students then have to opt for one of these challenges during the course. In this research, we aimed to get a more detailed understanding of what students consider to be important reasons to choose a particular challenge at the start of a CBL course.

In this research, we investigated the argumentation students used in the process of applying for a challenge in two different CBL courses. The results showed five categories of choice arguments: Content of the challenge, challenge characteristics, personal goals, personal background and collaboration. With a better understanding of student argumentation, expectation and motivation in CBL education, we contribute to the further advancement of transdisciplinary engineering education.

1 INTRODUCTION

1.1 The 'challenge' in challenge-based learning

STEM education is one of the most important tools for universities of technology to make impact on society. Not only by sharing the accumulated knowledge in these institutions with new generations of students, but also by enaging the students with the challenges in society. Universities are becoming learning ecosystems, where students engage in collaborations with societal partners that bring STEM education into their own organisations [1]. The complex challenges of today demand new approaches that organisations cannot come up with by themselve. In recent years, challenge-based learning (CBL) has arisen as a pedagogical structure for the collaborations between universities and a varied group of societal partners [2].

CBL makes an explicit connection between education and society and therefore fits the current strategic ambitions of many universities in the Netherlands to focus on impact for society. Central to CBL is the idea of learning evolving around a 'challenge' that connects societal needs to the problem solving attitudes of engineering students. A challenge in this type of education stems from a societal context, is inherently multidisciplinary and requires solutions to be collaboratively developed [3]. Without a doubt is CBL rooted in problem-based learning, where CBL deals with a more specific shape of 'problem' [4].

The exploration and identification of the project within the challenge is a crucial part of the CBL framework in STEM education. Not only does this step in the CBL process explicitly connect students' learning to (potential) professional practice in their future professional careers, it also highlights a student-centred approach [5]. Students to a large extend define within a challenge what their role and contribution to the problem solving process can be, by synthesising different sources of knowledge input, deal with the unknowns and defining the best approach (disciplining interdisciplinarity). They are confronted with the complexity and openness of a societal challenge and learn that there is not one solution. In line with self-determination theory, this is one of the core motivational aspects of CBL, as it offers autonomy, competence and relatedness to students to make their own decisions based on their interests [6].

The student-centred approach in CBL leads to openness and uncertainty on the side of the organisers of the course. Students may select topics that go beyond the expertise of the teachers or it is even unclear which expertises might be involved in looking for a solution. At the same time, CBL courses make use of real-life challenges, which means that public or private partners come into the university to collaborate with students. These partners find it hard to define a challenge, because they do not know what is important for the student learning process. Similarly, teachers look for new approaches to guide students in CBL and are in need of a better understanding of student motivation in this specific context [7].

The body of knowledge around challenge-based learning is growing. There are some studies that focus on the performance effects of challenge-based learning, but more detailed studies on the learning processes of students are lacking. These studies are important to inform and improve the teaching and learning framework of CBL and offer structure to all participants in these type of courses: teachers, partners and students.

1.2 Aim and research questions

In this research, we are interested to add more detail to the studies in CBL so far, by focussing on the first stage of choosing the challenge in the course. We do this by analysis of motivation letters in two different CBL courses at the University of Technology Delft (TU Delft). In these motivation letters, students had to put forward the argument why they wanted to take part in one of the challenges offered in the course. By analysing these arguments, we aim to answer two research questions:

1. What is the nature of the arguments that engineering students use to choose a challenge in a CBL course at the university?

2. What are the most important arguments for students to choose a challenge in a CBL course at the university?

By gaining a more detailed understanding of what drives students in these courses, we offer teachers and partners in these courses tools to navigate the student-centred approach. Additionaly, we aim to contribute to the further development of CBL learning and teaching frameworks in the future.

2 METHODOLOGY

2.1 Two cases

In this study, two cases were selected that fitted the CBL framework:

1. As part of the joint degree master MSc Metropolitan Analysis, Design and Engineering (MADE) by the TU Delft and Wageningen University & Research (WUR), students engage in a ‘Living Lab’ course that evolves around a

challenge arising from the Amsterdam Metropolitan Region. Over 7 months, students work in teams to develop a solution in co-creation with citizens, knowledge institute and private and public partners that fits their challenge and its context.

2. In the Joint Interdisciplinary Project (JIP) at the TU Delft, is a 2nd year elective master course of 10 weeks, open to all second year students before they graduate. The focus is on solving a company case, usually from the R&D department, in interdisciplinary groups and guided by a company coach, an academic coach and a course coach. The team is (depending on the company) partly embedded within the company and stimulated to consult professionals and academic experts to come up with innovative concept solutions in engineering design.

To set out the specifics of these courses next to each other, we use the framework as proposed by Malmqvist and Radberg [3] in their comparative study of challenge-based learning experiences (Table 1).

The two most eminent differences between the courses are, firstly, the backgrounds of the students. Although both courses have a multidisciplinary focus and attract students with different BSc backgrounds, in the Living Lab course students have had a joint first year of their MSc programme, while in JIP students that took part did not know each other and originate from different programmes. Secondly, the Living Lab students were involved in their challenges part-time over 7 months while the JIP students were involved in their challenges full-time over 10 weeks.

Table 1. Table Comparison of Challenge-based Learning Experiences

	JIP	**Living Lab MADE**
Student year	Year 5 (MSc year 2)	Year 5 (MSc year 2)
Learning outcomes	The ability to integrate (high quality scientific and practical technological) knowledge from different disciplines to solve complex problems and asses the impact of of the proposed solutions on society. An important part is the collaboration, communication and reflection on interdisciplinary teamwork and professional and personal development.	After following the Living Lab course, students will be able to design, facilitate and report upon a process of co-creation that aims at the design of an innovative product, relevant in a real-life, urban setting and contributing to enhanced urban sustainability in the Amsterdam Metropolitan Area.
Student backgrounds	Diverse cultural and disciplinary BSc and Master backgrounds. Mostly in Engineering and Science.	Multidisciplinary MSc programme “MADE” / Diverse BSc backgrounds

Taught topics	Focus on Professional skills development. Very brief introductory activities. E.g. on value based innovation, ethics, product design, teamwork, scrum, legal and financial issues.	Co-creation and experimentation in sustainable urban development.
Typical project	Students are asked to envision airtravel of the future. Sustainable energy sources, materials improvements, but also different ways of travelling and demographic/economic developments impact the way the world changes. Therefore it changes the business case of companies offering numerous possible paths for technological or other developments to change airtravel	Students are asked to design an intervention on the festival 'DGTL' that is aiming to become the first 'circular' festival in the world. Students are confronted with the challenges of circularity and think of ways to analyse the problems and design solutions.
Magnitude	15 ECTS	25 ECTS
Perspective	Global engineering topics	Metropolitan region (local)
Content focus	Sustainability, climate resilience, logistics, energy, health, mobility, digitisation, robotics	Mobility / climate resilience / food / circularity / energy / digitisation
Teacher team	Partners, project-dependent (academic) coach and course coordinator.	Partners, project-dependent (academic) coaches and three course coordinators
Students/year (estimated)	50	35

2.2 Motivation letters

In the two CBL cases studied here, motivation letters were used to have students provide an argumentation to choose a specific challenge. In both cases/courses, students chose a top 3 of their favorite challenges and wrote down the arguments of why these challenges fit their learning trajectory.

Looking at motivation letters offers a perspective on student motivation. Undoubtedly, students aim their motivation letters to the context that they are applying for and therefore the letters are written with a certain strategic aim in mind. The assignment to write a motivation letter in itself might activate specific schemata associated with selection procedures. However, the combination of motivation letters

in a complete student cohort can say something about the consideration and expectations that students have at the start of the course. It gives a detailed insight in students' perceptions of the challenges.

2.3 Open coding

The approach to the coding process has been realised as follows. The Living Lab case was used to establish a grounded set of codes through a process of open coding. In the initial grounded method of coding we tried to keep the coding across the two cases the same as much as possible. Where an argument did not fit the existing set of codes, a new code was added to the group.

Different arguments may have been used by one person and were coded accordingly. It means multiple excerpts with different codes may be from the same person. E.g. If in one motivation letter for choice A, I'm enthusiastic for the sustainability aspect and for choice B, logistics are the argument, both of them will be scored as being present for that student.

36 motivation letters were coded for the Living Lab course, resulting in 606 excerpts and the application of 881 codes. 35 motivation letters were coded for the JIP course, resulting in 253 excerpts and the application of 619 codes. The size of the motivation letters varied between 1-3 A4 pages in case of the Living Lab course and 1-2 A4 pages in case of the JIP course. The samples taken from both cases are therefore comparable in size. Cross-validation has not been realised yet.

3 RESULTS

3.1 The nature of arguments

Table 3 shows all arguments found by the process of open coding in both cases and how many times a certain code was used throughout the motivation letters. In total, 47 differently coded choice arguments were found. Between these codes, arguments had commonalities and we distilled five different groups of argumentation:

- **Content of the challenge:** the topics or themes that the challenge evolves around.
- **Challenge characteristics:** the uniqueness of the learning environment, the possibilities for experimentation or the professional environment.
- **Personal goals:** learning new skills, gaining new skills, experiences or career perspectives.
- **Personal background:** usually previous observations/lessons learned in work context, educational context, or in the homecountry context of the students.
- **Collaboration:** working together with groups from other disciplines, working together with different stakeholder groups.

3.2 The importance of arguments

To answer research question 2, we looked at the frequency with which certain arguments appeared in the motivation letters of students. Tables 4 and 5 show the ten most frequently mentioned arguments for each case. Five arguments appeared in both cases with a high frequency: Previous experience (327 times), collaboration different actor groups (121 times), learning new skills (96 times), sustainability (157 times) and societal impact (97 times). In this section, we discuss these choice arguments more elaborately.

Students in the Living Lab course mentioned 'previous experience' more often than any other argument (83 times). In a further investigation of the excerpts in the coding process, we created more specific codes to split this argument up into: BSc experience, existing skills, work experience, elective courses, curriculum courses and extracurricular activities. Students refered mostly (27 times) to BSc experience within these categories. Relating this to self-determintation theory, students show 'competence' based on their previous experiences in similar situations and use this as an argument for why they are capable of engaging with a specific case in their motivation letters [6]. Knowledge on the backgrounds of students, therefore, remains crucial in the selection process of challenges.

Table 2. Ten most frequently mentioned choice arguments in the Living Lab case.

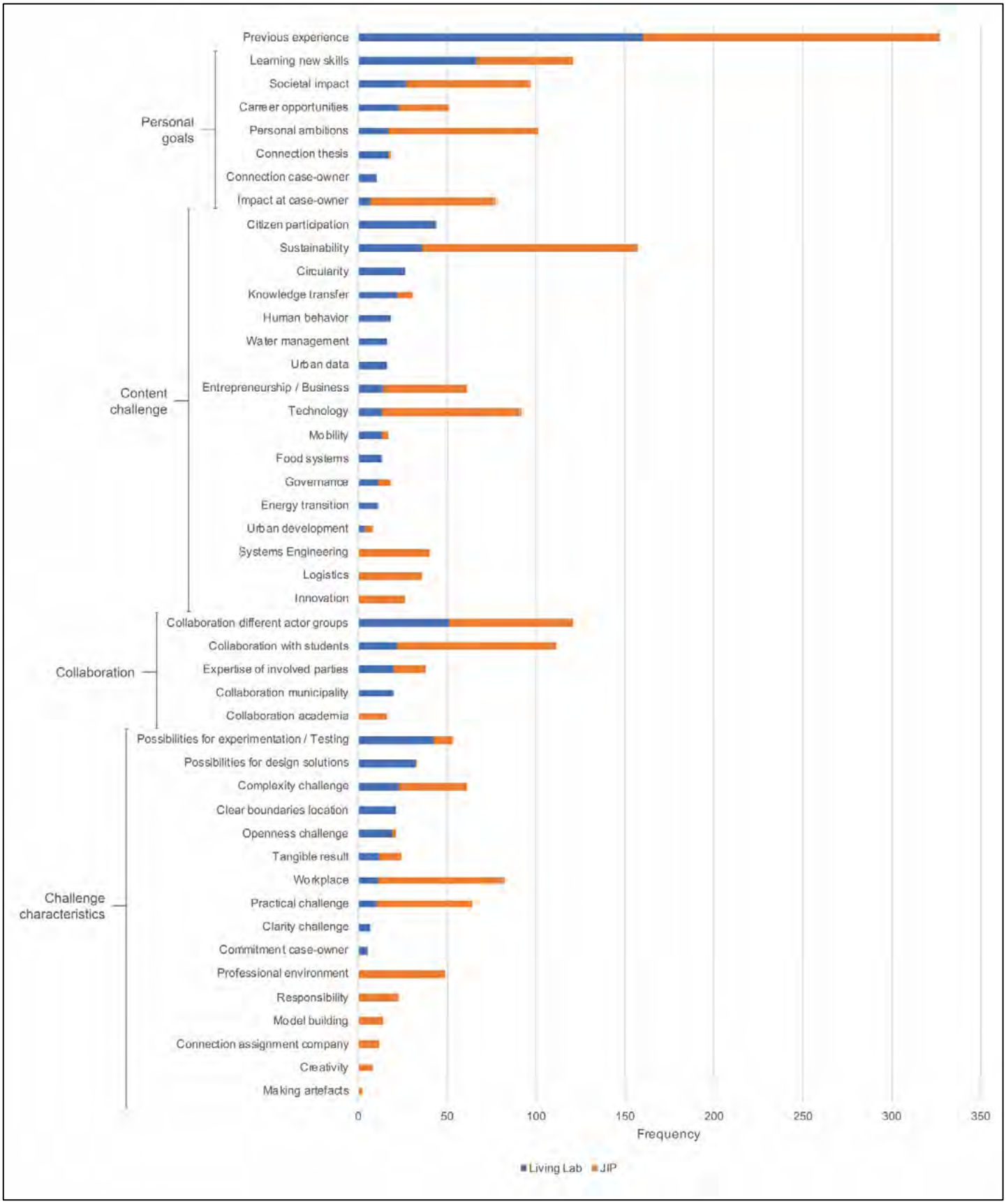
Name	Argument category	Mentions
Previous experience	Personal background	83
Collaboration different actor groups	Collaboration	51
Citizen participation	Content challenge	44
Possibilities for experimentation / Testing	Challenge characteristics	42
Learning new skills	Personal goals	41
Sustainability	Content challenge	36
Possibilities for design solutions	Challenge characteristics	32
Societal impact	Personal goals	27
Circularity	Content challenge	26
Complexity challenge	Challenge characteristics	23

Table 3. Ten most frequently mentioned choice arguments in the JIP case.

Name	Argument category	Mentions
Previous experience	Personal background	167
Sustainability	Content challenge	121
Collaboration with students with a different disciplinary background	Collaboration	89
Personal ambitions	Personal goals	84
Technology	Content challenge	79
Professional environment	Challenge characteristics	71
Collaboration different actor groups	Collaboration	70
Societal impact	Personal goals	70
Impact at case-owner	Personal goals	70
Learning new skills	Personal goals	55

Students want to learn new skills during the course and use this as a choice argument for challenges also. They use this argument roughly as often as 'societal impact', the other argument in the 'personal ambition' category. Both these choice arguments show the expectations that students have of what they might gain from the challenge. Similarly, many students describe they want to gain experience in 'collaboration with different actor groups' (121 times). One of the students describes this as follows: "Considering the different types of stakeholders (e.g. visitors, the municipality, energy providers), I would like to be able to work together with them and to have a role in maintaining this contact between all these different parties." In both cases, many students describe this need for a broad collaboration to be able to engage in the challenge.

Table 4. Frequency mentions of arguments in both case-studies.



When we look at what particular content the students are attracted by it shows that particularly the argument of sustainability is listed as main argument (157 times) in both cases. Additionally, students frequenly mention technology developments (79 times) and entrepreneurship/business (47 times) in the JIP and to a lesser extent in the Living Lab case. Students in the Living Lab course particularly mention circularity (26 times), and knowledge transfer (22 times), a topic that does not occur among the JIP students. A difference that can be explained by the shared background of the Living Lab students in a learning environment in which circularity is a common topic. Sustainability is often mentioned together with other codes, because students have experience with it, want to make an impact or have an ambition to develop these skills. In JIP sustainability relates in particular to the technological development. Sustainability is a broad notion and in this context needs further investigation to figure out the exact meaning for students in their choice arguments, the result illustrates a shared urgency among students to engage with sustainability challenges.

4 DISCUSSION

4.1 Implications of results and suggestions for further investigation

In this study, we have established an understanding of choice arguments and in this section we want to have a look at what practitioners of CBL can take from this study to apply in their own practice and how researchers can further investigate it. Teachers and partners considering the way to introduce the challenges to the students, could incorporate the five categories in order to connect to what drives students to engage in these courses and to show them different perspectives on the challenge. This study showed that it is not only important to pay attention to the content of the challenge, but also the opportunities it offers for learning new skills, collaboration with different actor groups and the societal impact students could make. Students are looking for what a challenge has to offer to their learning trajectories and for ways to make an impact on society.

Further research should look into this connection between the choice arguments and the learning trajectories of students in the course. CBL offers students the opportunity to make decisions about their own learning trajectories and this study offers insight in the expectations of students. A next question might be if these expectation are met by CBL and to what extend. We realise that a study, such as we have conducted here, that brings all choice arguments of students together to establish one common profile, does not allow to stress the uniqueness of personal arguments and backgrounds that impact decision making. However, students use different categories of choice arguments and it might be possible to discover patterns of decision making. In this study, we showed that certain choice arguments appear in close connection to each other and this needs further investgiation. We expect that it might be possible to distinguish different way of argumentations within this group of

students and this way, we might be able to establish several profiles of choice arguments.

4.2 Conclusions

The main purpose of our study was to gain a more detailed understanding as to what motivates students in their choice for a specific challenge in the context of challenge-based learning. We investigated the choice arguments used in motivation letters of 71 students in two different case-studies and found 5 categories of argumentation that students use: Content of the challenge, challenge characteristics, personal ambition, personal background and collaboration. Several choice arguments play a role in the decision that students make about the challenge simultaneously. At the same time, this study also shows that some arguments are more prevalent in this generation of students. Not only do students look at how they can contribute to a challenge based on previous experiences in education, work and personal life, they also value which skills they might gain in the process. More so do they show a connection to challenges that deal with sustainability and collaboration and that ultimately offer these students a way to make an impact on society. This sheds new light on a generation of students that feels a responsibility to engage with societal challenges and is growing to become the engineers of tomorrow.

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CHOOSING CHALLENGES IN CHALLENGE-BASED COURSES

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ABSTRACT

Challenge-based learning (CBL) is increasingly on the higher education agenda. In many universities of technology in the Netherlands, CBL is being implemented in engineering education programmes to prepare students to work on authentic, complex, societal challenges, provided by partners from outside of the university. Making societal impact is an important driver the introduction of CBL, however, on a more pedagogical level, little is known about the motivational aspects of student learning in these challenge-based transdisciplinary courses.

In CBL, self-regulation has a prominent role. In many instances, students are asked to make motivated decisions about their development trajectory within the CBL process. One of the first decisions students have to make in these type of learning configurations is what challenge they will work on. The structure of CBL courses often involves several partners that all present their own challenge to the students. Students then have to opt for one of these challenges during the course. In this research, we aimed to get a more detailed understanding of what students consider to be important reasons to choose a particular challenge at the start of a CBL course.

In this research, we investigated the argumentation students used in the process of applying for a challenge in two different CBL courses. The results showed five categories of choice arguments: Content of the challenge, challenge characteristics, personal goals, personal background and collaboration. With a better understanding of student argumentation, expectation and motivation in CBL education, we contribute to the further advancement of transdisciplinary engineering education.

1 INTRODUCTION

1.1 The 'challenge' in challenge-based learning

STEM education is one of the most important tools for universities of technology to make impact on society. Not only by sharing the accumulated knowledge in these institutions with new generations of students, but also by enaging the students with the challenges in society. Universities are becoming learning ecosystems, where students engage in collaborations with societal partners that bring STEM education into their own organisations [1]. The complex challenges of today demand new approaches that organisations cannot come up with by themselve. In recent years, challenge-based learning (CBL) has arisen as a pedagogical structure for the collaborations between universities and a varied group of societal partners [2].

CBL makes an explicit connection between education and society and therefore fits the current strategic ambitions of many universities in the Netherlands to focus on impact for society. Central to CBL is the idea of learning evolving around a 'challenge' that connects societal needs to the problem solving attitudes of engineering students. A challenge in this type of education stems from a societal context, is inherently multidisciplinary and requires solutions to be collaboratively developed [3]. Without a doubt is CBL rooted in problem-based learning, where CBL deals with a more specific shape of 'problem' [4].

The exploration and identification of the project within the challenge is a crucial part of the CBL framework in STEM education. Not only does this step in the CBL process explicitly connect students' learning to (potential) professional practice in their future professional careers, it also highlights a student-centred approach [5]. Students to a large extend define within a challenge what their role and contribution to the problem solving process can be, by synthesising different sources of knowledge input, deal with the unknowns and defining the best approach (disciplining interdisciplinarity). They are confronted with the complexity and openness of a societal challenge and learn that there is not one solution. In line with self-determination theory, this is one of the core motivational aspects of CBL, as it offers autonomy, competence and relatedness to students to make their own decisions based on their interests [6].

The student-centred approach in CBL leads to openness and uncertainty on the side of the organisers of the course. Students may select topics that go beyond the expertise of the teachers or it is even unclear which expertises might be involved in looking for a solution. At the same time, CBL courses make use of real-life challenges, which means that public or private partners come into the university to collaborate with students. These partners find it hard to define a challenge, because they do not know what is important for the student learning process. Similarly, teachers look for new approaches to guide students in CBL and are in need of a better understanding of student motivation in this specific context [7].

The body of knowledge around challenge-based learning is growing. There are some studies that focus on the performance effects of challenge-based learning, but more detailed studies on the learning processes of students are lacking. These studies are important to inform and improve the teaching and learning framework of CBL and offer structure to all participants in these type of courses: teachers, partners and students.

1.2 Aim and research questions

In this research, we are interested to add more detail to the studies in CBL so far, by focussing on the first stage of choosing the challenge in the course. We do this by analysis of motivation letters in two different CBL courses at the University of Technology Delft (TU Delft). In these motivation letters, students had to put forward the argument why they wanted to take part in one of the challenges offered in the course. By analysing these arguments, we aim to answer two research questions:

1. What is the nature of the arguments that engineering students use to choose a challenge in a CBL course at the university?

2. What are the most important arguments for students to choose a challenge in a CBL course at the university?

By gaining a more detailed understanding of what drives students in these courses, we offer teachers and partners in these courses tools to navigate the student-centred approach. Additionaly, we aim to contribute to the further development of CBL learning and teaching frameworks in the future.

2 METHODOLOGY

2.1 Two cases

In this study, two cases were selected that fitted the CBL framework:

1. As part of the joint degree master MSc Metropolitan Analysis, Design and Engineering (MADE) by the TU Delft and Wageningen University & Research (WUR), students engage in a ‘Living Lab’ course that evolves around a challenge arising from the Amsterdam Metropolitan Region. Over 7 months,

students work in teams to develop a solution in co-creation with citizens, knowledge institute and private and public partners that fits their challenge and its context.

2. In the Joint Interdisciplinary Project (JIP) at the TU Delft, is a 2nd year elective master course of 10 weeks, open to all second year students before they graduate. The focus is on solving a company case, usually from the R&D department, in interdisciplinary groups and guided by a company coach, an academic coach and a course coach. The team is (depending on the company) partly embedded within the company and stimulated to consult professionals and academic experts to come up with innovative concept solutions in engineering design.

To set out the specifics of these courses next to each other, we use the framework as proposed by Malmqvist and Radberg [3] in their comparative study of challenge-based learning experiences (Table 1).

The two most eminent differences between the courses are, firstly, the backgrounds of the students. Although both courses have a multidisciplinary focus and attract students with different BSc backgrounds, in the Living Lab course students have had a joint first year of their MSc programme, while in JIP students that took part did not know each other and originate from different programmes. Secondly, the Living Lab students were involved in their challenges part-time over 7 months while the JIP students were involved in their challenges full-time over 10 weeks.

Table 1. Table Comparison of Challenge-based Learning Experiences

	JIP	**Living Lab MADE**
Student year	Year 5 (MSc year 2)	Year 5 (MSc year 2)
Learning outcomes	The ability to integrate (high quality scientific and practical technological) knowledge from different disciplines to solve complex problems and asses the impact of of the proposed solutions on society. An important part is the collaboration, communication and reflection on interdisciplinary teamwork and professional and personal development.	After following the Living Lab course, students will be able to design, facilitate and report upon a process of co-creation that aims at the design of an innovative product, relevant in a real-life, urban setting and contributing to enhanced urban sustainability in the Amsterdam Metropolitan Area.
Student backgrounds	Diverse cultural and disciplinary BSc and Master backgrounds. Mostly in Engineering and Science.	Multidisciplinary MSc programme “MADE” / Diverse BSc backgrounds

Taught topics	Focus on Professional skills development. Very brief introductory activities. E.g. on value based innovation, ethics, product design, teamwork, scrum, legal and financial issues.	Co-creation and experimentation in sustainable urban development.
Typical project	Students are asked to envision airtravel of the future. Sustainable energy sources, materials improvements, but also different ways of travelling and demographic/economic developments impact the way the world changes. Therefore it changes the business case of companies offering numerous possible paths for technological or other developments to change airtravel	Students are asked to design an intervention on the festival 'DGTL' that is aiming to become the first 'circular' festival in the world. Students are confronted with the challenges of circularity and think of ways to analyse the problems and design solutions.
Magnitude	15 ECTS	25 ECTS
Perspective	Global engineering topics	Metropolitan region (local)
Content focus	Sustainability, climate resilience, logistics, energy, health, mobility, digitisation, robotics	Mobility / climate resilience / food / circularity / energy / digitisation
Teacher team	Partners, project-dependent (academic) coach and course coordinator.	Partners, project-dependent (academic) coaches and three course coordinators
Students/year (estimated)	50	35

2.2 Motivation letters

In the two CBL cases studied here, motivation letters were used to have students provide an argumentation to choose a specific challenge. In both cases/courses, students chose a top 3 of their favorite challenges and wrote down the arguments of why these challenges fit their learning trajectory.

Looking at motivation letters offers a perspective on student motivation. Undoubtedly, students aim their motivation letters to the context that they are applying for and therefore the letters are written with a certain strategic aim in mind. The assignment to write a motivation letter in itself might activate specific schemata associated with selection procedures. However, the combination of motivation letters

in a complete student cohort can say something about the consideration and expectations that students have at the start of the course. It gives a detailed insight in students' perceptions of the challenges.

2.3 Open coding

The approach to the coding process has been realised as follows. The Living Lab case was used to establish a grounded set of codes through a process of open coding. In the initial grounded method of coding we tried to keep the coding across the two cases the same as much as possible. Where an argument did not fit the existing set of codes, a new code was added to the group.

Different arguments may have been used by one person and were coded accordingly. It means multiple excerpts with different codes may be from the same person. E.g. If in one motivation letter for choice A, I'm enthusiastic for the sustainability aspect and for choice B, logistics are the argument, both of them will be scored as being present for that student.

36 motivation letters were coded for the Living Lab course, resulting in 606 excerpts and the application of 881 codes. 35 motivation letters were coded for the JIP course, resulting in 253 excerpts and the application of 619 codes. The size of the motivation letters varied between 1-3 A4 pages in case of the Living Lab course and 1-2 A4 pages in case of the JIP course. The samples taken from both cases are therefore comparable in size. Cross-validation has not been realised yet.

3 RESULTS

3.1 The nature of arguments

Table 3 shows all arguments found by the process of open coding in both cases and how many times a certain code was used throughout the motivation letters. In total, 47 differently coded choice arguments were found. Between these codes, arguments had commonalities and we distilled five different groups of argumentation:

- **Content of the challenge:** the topics or themes that the challenge evolves around.
- **Challenge characteristics:** the uniqueness of the learning environment, the possibilities for experimentation or the professional environment.
- **Personal goals:** learning new skills, gaining new skills, experiences or career perspectives.
- **Personal background:** usually previous observations/lessons learned in work context, educational context, or in the homecountry context of the students.
- **Collaboration:** working together with groups from other disciplines, working together with different stakeholder groups.

3.2 The importance of arguments

To answer research question 2, we looked at the frequency with which certain arguments appeared in the motivation letters of students. Tables 4 and 5 show the ten most frequently mentioned arguments for each case. Five arguments appeared in both cases with a high frequency: Previous experience (327 times), collaboration different actor groups (121 times), learning new skills (96 times), sustainability (157 times) and societal impact (97 times). In this section, we discuss these choice arguments more elaborately.

Students in the Living Lab course mentioned 'previous experience' more often than any other argument (83 times). In a further investigation of the excerpts in the coding process, we created more specific codes to split this argument up into: BSc experience, existing skills, work experience, elective courses, curriculum courses and extracurricular activities. Students refered mostly (27 times) to BSc experience within these categories. Relating this to self-determintation theory, students show 'competence' based on their previous experiences in similar situations and use this as an argument for why they are capable of engaging with a specific case in their motivation letters [6]. Knowledge on the backgrounds of students, therefore, remains crucial in the selection process of challenges.

Table 2. Ten most frequently mentioned choice arguments in the Living Lab case.

Name	Argument category	Mentions
Previous experience	Personal background	83
Collaboration different actor groups	Collaboration	51
Citizen participation	Content challenge	44
Possibilities for experimentation / Testing	Challenge characteristics	42
Learning new skills	Personal goals	41
Sustainability	Content challenge	36
Possibilities for design solutions	Challenge characteristics	32
Societal impact	Personal goals	27
Circularity	Content challenge	26
Complexity challenge	Challenge characteristics	23

Table 3. Ten most frequently mentioned choice arguments in the JIP case.

Name	Argument category	Mentions
Previous experience	Personal background	167
Sustainability	Content challenge	121
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Impact at case-owner	Personal goals	70
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Students want to learn new skills during the course and use this as a choice argument for challenges also. They use this argument roughly as often as 'societal impact', the other argument in the 'personal ambition' category. Both these choice arguments show the expectations that students have of what they might gain from the challenge. Similarly, many students describe they want to gain experience in 'collaboration with different actor groups' (121 times). One of the students describes this as follows: "Considering the different types of stakeholders (e.g. visitors, the municipality, energy providers), I would like to be able to work together with them and to have a role in maintaining this contact between all these different parties." In both cases, many students describe this need for a broad collaboration to be able to engage in the challenge.

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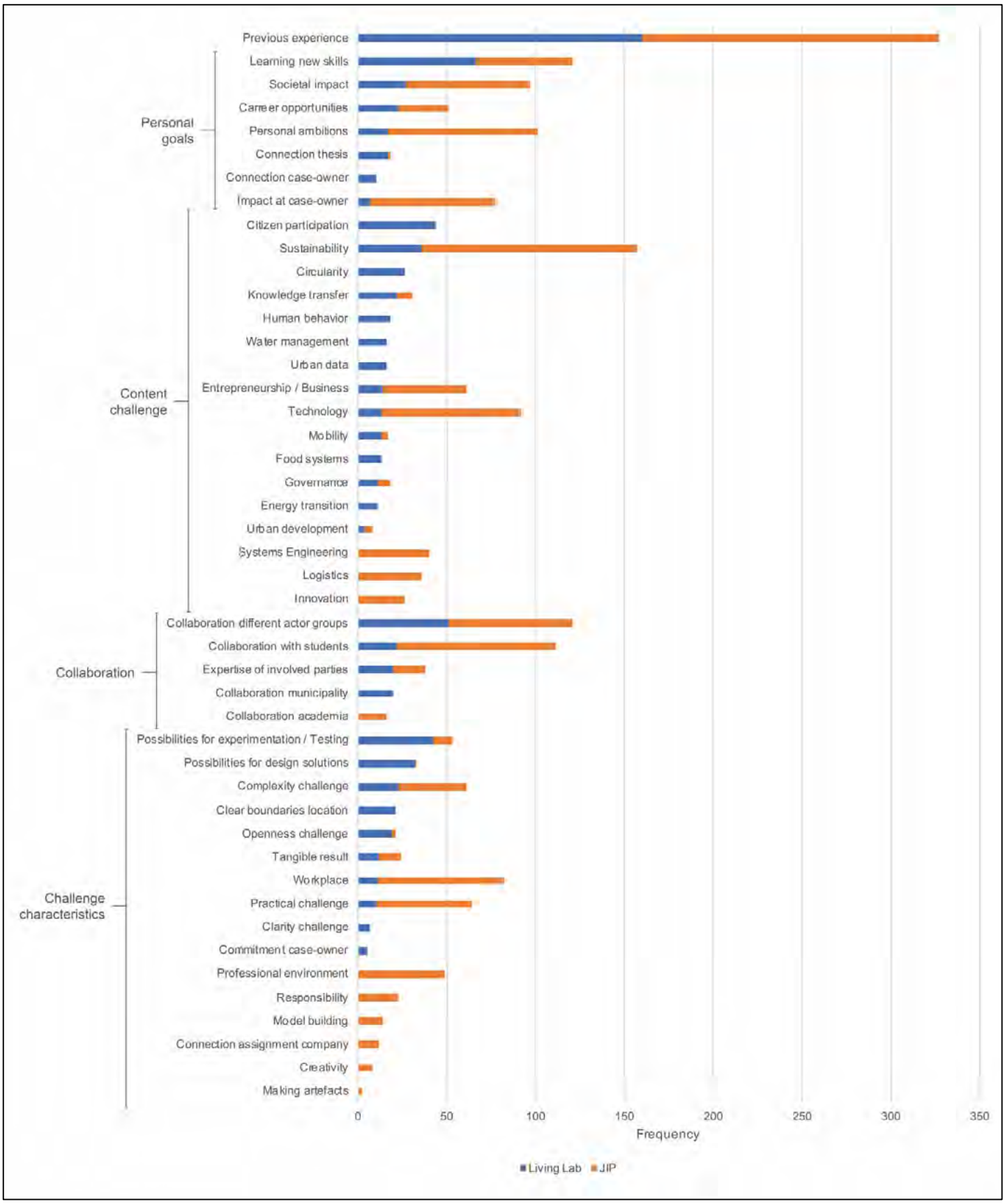

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4.1 Implications of results and suggestions for further investigation

In this study, we have established an understanding of choice arguments and in this section we want to have a look at what practitioners of CBL can take from this study to apply in their own practice and how researchers can further investigate it. Teachers and partners considering the way to introduce the challenges to the students, could incorporate the five categories in order to connect to what drives students to engage in these courses and to show them different perspectives on the challenge. This study showed that it is not only important to pay attention to the content of the challenge, but also the opportunities it offers for learning new skills, collaboration with different actor groups and the societal impact students could make. Students are looking for what a challenge has to offer to their learning trajectories and for ways to make an impact on society.

Further research should look into this connection between the choice arguments and the learning trajectories of students in the course. CBL offers students the opportunity to make decisions about their own learning trajectories and this study offers insight in the expectations of students. A next question might be if these expectation are met by CBL and to what extend. We realise that a study, such as we have conducted here, that brings all choice arguments of students together to establish one common profile, does not allow to stress the uniqueness of personal arguments and backgrounds that impact decision making. However, students use different categories of choice arguments and it might be possible to discover patterns of decision making. In this study, we showed that certain choice arguments appear in close connection to each other and this needs further investgiation. We expect that it

might be possible to distinguish different way of argumentations within this group of students and this way, we might be able to establish several profiles of choice arguments.

4.2 Conclusions

The main purpose of our study was to gain a more detailed understanding as to what motivates students in their choice for a specific challenge in the context of challenge-based learning. We investigated the choice arguments used in motivation letters of 71 students in two different case-studies and found 5 categories of argumentation that students use: Content of the challenge, challenge characteristics, personal ambition, personal background and collaboration. Several choice arguments play a role in the decision that students make about the challenge simultaneously. At the same time, this study also shows that some arguments are more prevalent in this generation of students. Not only do students look at how they can contribute to a challenge based on previous experiences in education, work and personal life, they also value which skills they might gain in the process. More so do they show a connection to challenges that deal with sustainability and collaboration and that ultimately offer these students a way to make an impact on society. This sheds new light on a generation of students that feels a responsibility to engage with societal challenges and is growing to become the engineers of tomorrow.

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LEARNING HAS NO END - LIFELONG LEARNING COMPETENCES FOR ENGINEERING STUDENTS

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ABSTRACT

Lifelong learning (LLL) has become an integral part of professional life. Universities have to make their students aware of their professional identity and train them in continuously re-inventing themselves. Lifelong learning, however, is complex and requires a variety of personal resources. In this exploratory study the aim is to get an overview of the current LLL competences of engineering students at the Faculty of Engineering Technology, KU Leuven and the Faculty of Applied Engineering, Univerity of Antwerp. In order to achieve this, a generic lifelong learning scale developed by Kirby et al. (2010) is used. A small, but significant, difference between the LLL competences of bachelor and master students is found.

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1 INTRODUCTION

Lifelong learning (LLL) has become an integral part of professional life. Continuously updating and up-skilling of competences is necessary in order to keep pace with the changing requirements of the labour market [1,2]. Looking more specifically at engineers, the half-life of an engineer's technical knowledge is limited to two to seven years depending on the discipline [3]. Higher education institutions have a leading role in delivering engineers with lifelong learning competences. Universities have to make their students aware of their professional identity and train them in continuously re-inventing themselves. As stated by [4] lifelong learning is a key aspect for future engineering education. Lifelong learning competencies, however, are complex and can be described by different definitions. For example, a recent study [5] identified the following four factors having an effect on the lifelong learning of students: curiosity, openness to learning, access to information and information literacy, and self-direction and self-evaluation. Another study [6] distinguished six subscales: self-management competencies, learning how to learn competencies, initiative and entrepreneur competencies, competencies of acquiring information, digital competencies, and decision-taking competencies. De Keyzer et al. [7] stated that for lifelong learning, students should have (1) the willingness to look out for and take advantage of learning occasions, (2) the ability to do self-direct learning (set goals, plan and execute, (re)evaluate and draw learning gains) and (3) knowledge of means to do so [7]. The openness for developing lifelong learning skills is bound to be determined by the attitude of students as well as the students' self-esteem regarding those skills. In other words: self-regulated learning (SRL) is a key factor for lifelong learning.

In this study the aim is to get an overview of the current LLL competences of engineering students at the Faculty of Engineering Technology, KU Leuven, and the Faculty of Applied Engineering, University of Antwerp. Though the names of these faculties suggest a differing nature, they educate towards the same master degree. Comparing both faculties goes beyond the scope of this study. Consequently, the participants are combined into one sample.

2 METHODOLOGY

2.1 Instrument

In order to measure the LLL competences of students, a questionnaire developed by [8] is used. Their generic lifelong learning scale, consisting of 14 items, focuses on the following constructs [9]: (1) Goal setting, (2) Application of knowledge and skills, (3) Self-direction and evaluation, (4) Locating information, (5) Adaptable learning strategies. The questionnaire is self-reported and participants are asked to answer on a five-point Likert scale (1= Totally disagree and 5= Totally agree). In their study [8] the Cronbach alpha was 0.71, which is considered as a reasonable reliability, especially since lifelong learning is a complex construct. The factor analysis resulted in one single factor.

2.2 Sample

The link for the online LLL questionnaire is distributed to 2nd year bachelor's, 3rd year bachelor's, transfer students, and master students of the Faculty of Engineering Technology, KU Leuven, and the Faculty of Applied Engineering, University of Antwerp. Participation in the study was voluntary and completely anonymous. A total of 160 engineering students completed the online survey.

2.3 Hypotheses

In this study two main hypotheses are formulated below:

- Hypothesis 1: Master students obtain a higher level of LLL competences than bachelor students.
- Hypothesis 2: There is no difference in the LLL competences of master students that followed the regular study programme and the ones that entered the master's programme via the transfer programme (i.e. an alternative pathway).

The next section includes, besides the outcomes of the hypotheses, descriptive statistics and the internal consistency of the survey.

3 RESULTS

3.1 Summary and descriptive statistics

Table 1 shows the distribution of the students' answer for each of the 14 items. The descriptive statistics of the items are presented in Table 2. The mean sum score of the LLL survey is 3.37 (SD=.32).

Table 1. Descriptive statistics and item-total correlations (Rit) LLL survey

Lifelong Learning items		Mean	SD	Rit
Q1r	I prefer to have others plan my learning	2.93	.935	.074
Q2r	I prefer problems for which there is only one solution	3.42	.921	.223
Q3	I can deal with the unexpected and solve problems as they arise	3.91	.558	.253
Q4r	I feel uncomfortable under conditions of uncertainty	2.56	.845	.201
Q5	I am able to impose meaning upon what others see as disorder	3.54	.751	.177
Q6r	I seldom think about my own learning and how to improve it	3.09	1.15	-.001
Q7	I feel I am a self-directed learner	3.60	.856	.219
Q8r	I feel others are in a better position than I am to evaluate my success as a student	3.28	.951	.149
Q9	I love learning for its own sake	3.36	1.01	.418
Q10	I try to relate academic learning to practical issues	3.84	.765	.281
Q11r	I often find it difficult to locate information when I need it	3.04	.924	.314
Q12	When I approach new material, I try to relate it to what I already know	3.94	.741	.235
Q13	It is my responsibility to make sense of what I learn at school	3.38	.923	.100
Q14r	When I learn something new I try to focus on the details rather than on the 'big picture'	3.37	.895	-.037

Table 2. Answer distribution – Merged Liktert scale: 1&2= disagree, 3= neutral, 4&5= agree Note. r=reversed item

Lifelong learning items		Bachelor students (N=82)			Transfer students (N=13)			Master students (N=65)			Total (N=160)		
		N disagree	N neutral	N agree	N disagree	N neutral	N agree	N disagree	N neutral	N agree	N disagree	N neutral	N agree
Q1r	I prefer to have others plan my learning	24 (29%)	28 (34%)	30 (37%)	4 (31%)	9 (69%)	0 (0%)	19 (29%)	16 (25%)	30 (46%)	47 (29%)	53 (33%)	60 (38%)
Q2r	I prefer problems for which there is only one solution	42 (51%)	23 (28%)	17 (21%)	5 (38%)	4 (31%)	4 (31%)	40 (62%)	18 (28%)	7 (11%)	87 (54%)	45 (28%)	28 (18%)
Q3	I can deal with the unexpected and solve problems as they arise	3 (4%)	11 (13%)	68 (83%)	0 (0%)	3 (23%)	10 (77%)	2 (3%)	4 (6%)	59 (91%)	5 (3%)	18 (11%)	137 (86%)
Q4r	I feel uncomfortable under conditions of uncertainty	11 (13%)	24 (29%)	47 (57%)	2 (15%)	3 (23%)	8 (62%)	11 (17%)	24 (37%)	30 (46%)	24 (15%)	51 (32%)	85 (53%)
Q5	I am able to impose meaning upon what others see as disorder	8 (10%)	29 (35%)	45 (55%)	0 (0%)	7 (54%)	6 (46%)	2 (3%)	23 (35%)	40 (62%)	10 (6%)	59 (37%)	91 (57%)
Q6r	I seldom think about my own learning and how to improve	43 (52%)	11 (13%)	28 (34%)	5 (38%)	3 (23%)	5 (38%)	29 (45%)	11 (17%)	25 (38%)	77 (48%)	25 (16%)	58 (36%)
Q7	I feel I am a self-directed learner	10 (12%)	24 (29%)	48 (59%)	3 (23%)	6 (46%)	4 (31%)	5 (8%)	13 (20%)	47 (72%)	18 (11%)	43 (27%)	99 (62%)
Q8r	I feel others are in a better position than I am to evaluate my success as a student	35 (43%)	26 (32%)	21 (26%)	4 (31%)	3 (23%)	6 (46%)	34 (52%)	20 (31%)	11 (17%)	73 (46%)	49 (31%)	38 (24%)
Q9	I love learning for its own sake	19 (23%)	29 (35%)	34 (41%)	0 (0%)	5 (38%)	8 (62%)	8 (12%)	17 (26%)	40 (62%)	27 (17%)	51 (32%)	82 (51%)
Q10	I try to relate academic learning to practical issues	5 (6%)	20 (24%)	57 (70%)	1 (8%)	0 (0%)	12 (92%)	3 (5%)	11 (17%)	51 (78%)	9 (6%)	31 (19%)	120 (75%)
Q11r	I often find it difficult to locate information when I need it	32 (39%)	30 (37%)	20 (24%)	7 (54%)	3 (23%)	3 (23%)	18 (28%)	18 (28%)	29 (45%)	57 (36%)	51 (32%)	52 (33%)
Q12	When I approach new material, I try to relate it to what I already know	3 (4%)	16 (20%)	63 (77%)	0 (0%)	1 (8%)	12 (92%)	4 (6%)	8 (12%)	53 (82%)	7 (4%)	25 (16%)	128 (80%)
Q13	It is my responsibility to make sense of what I learn at school	16 (20%)	28 (34%)	38 (46%)	1 (8%)	2 (15%)	10 (77%)	14 (22%)	17 (26%)	34 (52%)	31 (19%)	47 (29%)	82 (51%)
Q14r	When I learn something new I try to focus on the details rather than on the 'big picture'	40 (49%)	20 (24%)	22 (27%)	7 (54%)	5 (38%)	1 (8%)	38 (58%)	19 (29%)	8 (12%)	85 (53%)	44 (28%)	31 (19%)

3.2 Internal consistency

This study found a Cronbach's Alpha of .52, which is below the required .70 to be considered as acceptable. The interpretation of the item-total correlations (Rit) according to the thumb rules of Ebel [10]: poor (Rit<0.20), doubtful (0.21< Rit< 0.29), good (0.30< Rit <.039), and very good (Rit >0.40), resulted in six poor, six doubtful, one good, and one very good item (Table 2).

3.3 Differences in LLL competences

Performing an ANOVA[2] analysis showed no significant differences between the different groups of students (F=1.260, p=.288). An independent samples T-test[3] was conducted between the regular master students and master students who entered the programme via an alternative pathway and no significant difference was found (T=.124, p=.902).

Table 3. Lifelong learning for different student groups

LLL for different student groups	N	Mean	SD
2nd year bachelor's	38	3.32	.268
3rd year bachelor's	44	3.32	.334
Transfer	13	3.40	.257
Master's	43	3.43	.346
Master's via transfer programme	22	3.44	.348
Total	**160**	**3.37**	**.320**

The students were also merged into two groups: bachelor students (M=3.32, SD=.303, N=82) and master students (M=3.44, SD=.344, N=65). An independent samples T-test[4] showed a significant difference between the two groups (T=2.20, p=.029). Appendix A presents the mean scores for each individual item for both the bachelor and master students.

By way of comparison, we compared our results (M=3.37, SD=.320, N=160) with the ones in the orginal paper (M=3.72, SD=.410, N=309) [8] and conducted an independent samples T-test. This showed a significant higher mean score for the pilot in the orginal study (T=9.413, p<.0001). Since the original study [8] included only final year students, the same analysis is performed with only the master students (M=3.44, SD=.344, N=65), which also resulted in a significant difference (T= 5.145, p<.0001).

[2,3,4] Levene's test showed that homogeneity of variances can be assumed.

4 DISCUSSION

4.1 Hypotheses

A small, but significant, difference between the LLL competences of bachelor and master students is found, which is in line with hypothesis 1, namely that master students achieve a higher level of LLL competences. No statements, however, can be made about how many students have appropriate LLL competences. It will be important to define in further research (1) what determines approptiate LLL competences and (2) what will be the threshold to make a distinction between 'inadequate' and 'proper' LLL competences. In comparison to the orginal study [8], the participants in our study obtained a significant lower mean score on the LLL survey. This is an indication that Flemish Engineering students possess a lower level of LLL competences, which will be further examined in future work.

It is reassuring that there are no differences in LLL competences between regular master students and master students who entered the programme via an alternative pathway. After all, it is important that at the end, all graduates obtainsimilar LLL competences, regardless of their study pathway. At the end of the study programme, similar learning outcomes are pursued irrespectively of the students' study pathway.

4.2 Individual items

Given the exploratory character of the study and the low consistency within the questionnaire, it is worthwhile to analyse some of the questions separately.

For instance, only a third of the participants (29%, N=47) prefer to plan their own learning (Q1). Even in the final year, only 29% (N=19) of the master students prefer to plan their own learning. Almost half of the master students (46%, N=30) prefer to have others plan their learning, while 25% (N=16) are undecided. In addition, 36% of the total group (N=58) indicate that they only seldom think about their own learning and how they can improve it (Q6). Both these results can be an indication that there is not enough awareness of the importance of lifelong learning among students. An important element, when fostering students' LLL attitude, will be to focus on increasing the awareness of the importance of LLL [11]. In another study [12] focus group discussions, organised with faculties organizing programmes in Engineering Technology at the Flemish universities, showed that all universities acknowledge the great importance of LLL. They also point out that a possible manner to increase students' awareness is to include LLL more explicitly in the study programme. Introducing a LLL course in which each individual student (N=17) had to make a personal development plan, is one manner to make LLL more explicit [7]. Almost all the students (N=15, 88%) reported that they have learned to set goals, to self-assess and continuously (re)-evaluate their learning. Although they attribute the latter two abilities mostly to the entire curriculum, more than half of the students assign learning to set goals to the specific LLL course. In addition, 12 students state that they now

have the willingness to look out for formal, non-formal, and informal opportunities for further self-development.

A large majority of the participants in this study state that they try to relate (1) academic learning to practical issues (Q10, N=120, 75%) and (2) new material to what they already know (Q12, N=128, 80%). Also 86% (N=137) of the participants indicate that they feel comfortable tackling unexpected problems (Q3). These items seem to be related to direct problem-solving area's that are relevant for engineers. They might indicate that engineering students are capable of learning 'on the job' when the learning opportunity passes their path. This is a contrast to the 'planned' learning where a person would not only learn for the moment, but set up a plan for learning in order to tackle future problems (cfr. Q1 and Q6).

Surprisingly enough master students find it significantly more difficult to locate information (Q11) than bachelor students (T=2.073, p=.040). This might be due to master students being confronted with the difficulty of finding information for their master thesis or challenging project work. However, further and more in-depth research is required. With the exception of items Q1 and Q11, all other items seem to indicate an increase from bachelor to master, which is in line with hypothesis 1. The increase however is only significant for Q2: *"I prefer problems for which there is only one solution*" (T=-2.378, p=.019) and Q9: *"I love learning for its own sake"* (T=2,204, p=.029). 62% of the master students (N=40) state that they do not prefer problems for which there is only one solution and 28% (N=18) answers neutral on this item. This, off course, is a relief, since engineering problems rarely have one exact solution.

5 CONCLUSION AND FUTURE WORK

This exploratory study found significant higher scores on LLL competences for master students, which confirms one of the hypotheses of the research. The sample of this study, however obtaines significant lower scores than the sample of the study of which the survey was used [8]. The low internal consistency of the survey has to be studied in more detail since it is in conflict with the original paper [8]. Including LLL more explicitely can be a possible manner to increase the awareness for the importance of LLL as demonstrated by [7]. In future work it will be determined what the LLL concept means to the engineering profession. The results of another study [12] are the starting point. Student background variables were not taken into account in this study. It is however plausible that there are differences when they are included. In further research we will therefore control for background variables.

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APPENDIX A

Table 4. Mean item scores for bachelor (N=82) and master students (N=65)

	Mean item scores	Mean	SD
Q1	Master students	3.15	.988
	Bachelor students	3.08	.940
Q2	Master students	2.35	.856
	Bachelor students	2.71	.944
Q3	Master students	3.98	.545
	Bachelor students	3.86	.566
Q4	Master students	3.37	.858
	Bachelor students	3.51	.846
Q5	Master students	3.66	.735
	Bachelor students	3.46	.786
Q6	Master students	2.98	1.12
	Bachelor students	2.83	1.17
Q7	Master students	3.75	.811
	Bachelor students	3.57	.872
Q8	Master students	2.58	.900
	Bachelor students	2.78	.969
Q9	Master students	3.52	.970
	Bachelor students	3.16	1.03
Q10	Master students	3.94	.808
	Bachelor students	3.76	.742
Q11	Master students	3.15	.972
	Bachelor students	2.84	.848
Q12	Master students	4.00	.848
	Bachelor students	3.87	.677
Q13	Master students	3.37	.993
	Bachelor students	3.31	.869
Q14	Master students	2.51	.812
	Bachelor students	2.75	.935

FLIPPING ALL COURSES ON A SEMESTER: STUDENTS REACTIONS AND RECOMMENDATIONS

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ABSTRACT

Several universities have adopted flipped learning methods for teaching, offering increased student interaction, and different approaches to course preparation and learning processes. Flipped learning appears particularly well suited for engineering educations, as it can combine active and problem-based learning (PBL) activities. In spring 2019, a research project challenged a 4th semester at the Medialogy BSc programme to a 'flipped and integrated semester', where all courses applied flipped learning, and used the approach to integrate students' coursework into their semester project work. To measure the effect of the flipped and integrated semester approach, the 4th semester teacher team collaborated to include several initiatives, such as cross-course teaching activities, student activities for course- and project-integration, and integration-supporting supervision approaches, etc. Student responses to these changes were diverse, and while a part of the students were positive, there is a definite room for improvement. Most requested improvements included a strong semester structure and planning and an explicitly clear relationship between courses and the project. Flipped and integrated semesters require a lot of planning, communication, need a holistic structure and has to be transparently communicated to students. Also among students' main requests for improvement, were a consistent flipping approach across courses, clear connections between homework preparation material and in-class activities, and the inclusion of short introductory in-class clarification of preparation material before any in-class activities. If properly motivated to follow the steps, students found that the flipped classroom format could increase learning.

1 INTRODUCTION

Flipped learning approaches has been adapted by more and more universities, due to their ability to facilitate opportunities for expanded student interaction, and enhance the width of ways to engage the subject material. Having these freedoms can prove important for students' learning processes, if applied correctly (Johnson et al. 2015). From the combined perspectives of a constructivist ideology and instructional lectures, flipped learning approaches can be integrated advantageously within engineering educations, due to their handy consolidation of active and problem-based learning (PBL) activities (Karabulut-Ilgu et al. 2018). A variety of studies have been published on applying flipped classroom, flipped learning and blended learning to lectures. Between these studies, very different experiences has been reported between students and teachers, for instance in terms best practice on structure, learning outcome and resources needed to fulfill the requirements (Triantafyllou et al. 2016; Bertel & Svarre Kristensen 2018).

Since 1976, Aalborg University has applied its *AAU Model*, which includes the *AAU PBL principles* (Askehave et al. 2015) to guide teaching praxis: project organization creates the framework of PBL; courses support the project work; cooperation is a driving force in problem-based project work; the problem-based project work of the groups must be exemplary; students are responsible for their own learning achievements (Askehave et al. 2015). The principles cover three learning dimensions: 1) the problem, 2) the content and 3) the team. The typical application of the AAU PBL principles, if regarded from the perspective of semester construction, includes a governing semester description (the semester theme) to frame the scope, a set of courses which students follow for basic knowledge, skills and competences, and a problem-based semester project with learning objectives congruent with the semester theme.

The AAU Model has occasionally been revised to remain contemporary. However, the 2011 revision introduced an alteration that challenged the inherent compass of AAU PBL (Hüttel & Gnaur 2017). All courses were now required to be individually examined, replacing a modus where a portion of courses were evaluated based on a) their integration in the semester project and b) the students' proficiencies with the course curriculum at the project examination. The adjustment to step away from the project as the governing body for a collective of learning objectives, can now be seen as deceptively impactful. The ensuing years has shown a slow but certain disunion of courses and projects. Their role as mutual partners, and 'keepers' of a forgathered semester theme, is now showing signs of discontinuance with both students and teachers.

A recent ambition for AAU has become to constructively challenge the comprehension of its 'AAU Model' PBL ideology. Examples showing this incentive are the close to 30 small, AAU-funded PBL projects, aimed for internal researchers to exploring, question, challenge or examine a slice of the AAU PBL praxis. Several of these concerned flipped classroom-oriented approaches. Additionally, AAU also funded the '*Future Directions for Problem Based Learning in a Digital Age*' project - or *PBL Future* for short (Pblfuture.aau.dk); a 3-year research project aimed for deeper understanding of the inner pros and cons workings of the current model implementation, as well as new visions to take the AAU PBL principles into the next revised era.

A 'PBL Future' sub-project research group (the authors of this paper) have specifically invested their research in exploring the utilization of flipped learning, as a standard teaching approach for the digitalized future of AAU PBL. In spring 2019, a concept termed *'a flipped and integrated semester'* was proposed by the research group to a

4th semester AAU teacher team, at the Medialogy B.Sc. program. In such 'flipped and integrated semester', all courses would solely practice a flipped learning approach in teaching, while also seeking integration of integrate (Kofoed et al. 2018).
Medialogy as a field combines problem-solving, human-computer interaction, design and media technology, to create specific solutions for specific users, often in collaboration with stakeholders. The 4th semester of Medialogy (MED4) at Aalborg University Copenhagen, consists of three courses (5 ECTS each) and a semester project (15 ECTS), and the semester theme is '*Sound Computing and Sensor Technology*'. MED4 relies more heavily on math and programming compared to previous semesters, focusing more towards understanding user needs. Empirical survey data suggests that this semester profile means that many Medialogy students consider MED4 a particularly difficult semester. This is supported by internal data showing that many students fail the ordinary MED4 course exams (Kofoed et al. 2018), suggesting an inadequate learning outcome. For years, this trend has frustrated the MED4 teacher team, and made them susceptible to alternative approaches.
The concept of a flipped and integrated semester within a PBL environment is pedagogically a fitting combination, from the theoretical perspective of Jensen et al. (2015). Both are routed in active learning, and active participation has shown to lead to improved learning (Jensen et al. 2015), compared to passive learning which conversely has shown to impact performance negatively (Hackmann & Holmboe 2014). As one of the pioneers, Lage et al. (2000), defined a flipped (inverted) classroom as "*Inverting the classroom means that events that have traditionally taken place inside the classroom now are taking place outside the classroom and vice versa*" (Lage et al. 2000). Meanwhile, the 'flipped classroom' and 'flipped learning' concepts should not be confused as identical. Flipped classroom involves structure and framework of teaching, while flipped learning focuses on the processes and learning. The traditional, transmissive lecture is discharged with the flipped learning approach, overtaken by active in-class activities, for example peer learning, problem solving, and specific pedagogical approaches for out of class activities (Hackmann & Holmboe 2014). PBL is likewise occupied with active learning, as well as the emphasis on activating students in real-world oriented problem-solving processes, including peer learning.
The flipped and integrated semester was presented to the MED4 team including the following benefits: a) the support of a wider range of possible PBL-oriented student activities during in-class sessions, including even more student-teacher interaction, b) to increase connectedness between courses by (for instance) allowing more cross- and combined course dissemination and activities, and c) to introduce stronger integration of project and courses, by basing course activities on project-related needs, preparing initiating project descriptions which carefully subscribed to course contents, and to plan the sequencing of the courses to follow the project phases.
This paper marks the end of the first completion of such flipped and integrated semester; a 5-month process working with teachers to adapt flipped learning, as a tool to advance their teaching experiences, and invite them to test and explore the utilization of digitalized content distribution with new roles for the effective course dissemination. But more fundamentally; to reintroduce the explicit ambition of a cross-course and course-project integration to the AAU semester. This paper will primarily contribute to the PBL community, with a discussion of the flipped and integrated semester concept, largely based on a presentation of results from the concluding student evaluation of the first full iteration of the flipped and integrated semester.

2 METHODS

The three flipped semester courses were *Audio Processing* (AP), *Design & Analysis of Experiments* (DAE), and *Physical Interface Design* (PID). DAE had experimented with flipped classroom prior to the flipped and integrated semester, but AP and PID had no experience. Leading up to semester start, teachers and PBL researchers discussed approaches to flipping, decided to approximate teachers' approach closely to DAE's adaptation; video material, readings and quizzes were provided for out-of-class homework preparation for the in-class session. In-class sessions started with a short discussion on the preparation homework, proceeding quickly to an activity-based scheme, typically group exercises performed with teacher/TA assistance, and routinely broken a bit, by the teacher calling for a short detailing to the whole class, if a challenge would telegraph itself likely to be shared by many students. AP and PID needed to find their feet in this approach, and find or develop out-of-class material. In addition, workshops were provided throughout the semester, providing an extended version of the in-class lecture activity scheme. Some workshops focused primarily on individual courses, while others sought to combine considerations both several courses and the semester project.

During the semester progression, the teacher team exchanged experiences internally and at meetings, and adjusted the teaching accordingly. Examples include the amount of readings, the explanation of the purpose of readings or tasks, the in-class sessions, etc. During the semester, one role of the PBL research team was to facilitate and (if needed) mediate the dialogues between teachers. Another was to observe and collect information and insights about the progress of the semester, based partly on observations, but also student responses from surveys regularly provided to students throughout the semester. The information from surveys was then presented to teachers, for them to adapt accordingly, if needed. The methodology for the research group was primarily approaching the study as an explorative case study (Stebbins 2001, Remenyi 2013), and a descriptive, mixed-method study (Stake 1995, Yin 2008). Four questionnaires were sent to students during the semester, focusing primarily on the same aspects. It is the fourth and final questionnaire, requesting students' final evaluation of the semester, which this paper focuses on. All the four questionnaires were built using predominantly quantitative rating on students' experience of the flipped lectures (as this would be the first time many of them had tried that). More specifically, main categories were the level of integration of project considerations in courses, students' perceived course workload, their perceived difficulty of the courses, and the perceived learning outcome from courses. Lastly, students were asked about the integration of course work into their project, and overall aspects to their semester project experience. The questionnaire had 44 quantitative items and 17 open-ended (qualitative) items, split into 15 small sections, covering the categories just mentioned. After each of the 15 sections, one of the 17 open-ended items would follow, as voluntary response options requesting elaboration from students on the ratings they gave in the section, if students would care to elaborate on their rating. Besides these follow-ups, the last open ended items were an opening "describe your MED4 experience" and a closing "if you have any additional comments, please add'. In the following, we will present the evaluation results. The questionnaire was provided to students on October 8th 2019. At this time, all participating students had completed MED4, including all exams, and had a complete impression of the semester.

3 RESULTS

The questionnaire received 40 responses out of 59 registered students on the semester. This is considered a satisfactory cut of the population. The following results presentation will be disseminated in formulated form, with tendencies informed by the quantitative ratings, and rationalized based on the open-ended responses.
The key contribution here, is the summative conclusions and future recommendations to a flipped and integrating semester, from students who a) have been used to traditional course work + a weakly integrated PBL project, but b) is then removed completely from this comfort zone, c) exclusively exposed to flipped learning course-work for an entire semester, d) from teachers with mixed experiences, e) on a semester with a very steep learning curve, and f) with a semester coordinator who has had to understand how to plan the semester around it. Exposing the governing take-away already here; findings will suggest a definite potential for the flipped and integrated semester, but also show that flipped learning is a craft that needs a lot of initiating investments, practical experiences and specific application to the target audience. Another key finding is that flipping an entire semester at once, for the first time, is a deceptively large task, that demands constant and very high levels of communication between teachers, as well as frequent dialogue with students to understand their perceptions and needs.

In the opening item; the exclusively open-ended experience description from students, the semester was depicted with positive references from an overall appreciation of the holistic approach to the flipped courses, including the teaching method applied by teachers and coordinators for both for courses and workshops, and showed an appreciation of capable and engaged teachers. Critique was more dominant than praise, however, pointing towards an absence of consistency and structure in the implementation of the flipped learning approach, especially for the two courses where teachers had less experience. Arguments included an overly tight and stressed schedule, and an extensive out-of-class preparation quantities, which resulted in several topics covered in courses to manifest as a stressful experience. Another overall criticism was a perceived lack of coherence between the course curriculum as experienced during the lecture-run, compared to the final exam requirements.
For a more detailed look into some of these criticisms, responses on courses' *provided homework preparation material* prior to in-class activities was again perceived as well chosen by some students, while others criticised content. Argued by some to simply be 'boring', others raised quite relevant critiques by questioning the balance between the large preparation quantities and a perceived lack of useful application or logical purpose of the material, in relation to either the course learning objectives, or the transfer of the material into the in-class sessions. Students suggested a priority system (e.g. a split between mandatory and extended readings). Other critiques related to preparation material not produced by the teachers themselves, which made it feel distant, inadequate or irrelevant to the following in-class activity.
Concerning the *in-class activities* themselves, some students considered them fruitful and constructive for the understanding of the overall lecture content, though with a differentiating rank between the individual courses. Endorsements related to proper balancing and logic between preparation and in-class activities, but only if in-class sessions included good introductions to the prepared material, and was complemented with clear descriptions of the expected application and outcomes for the in-class exercises. Appreciation was also given to sessions including considerations or practical work supporting the semester project. Critique aimed at in-

class sessions that served as mere repetition of the homework preparation, and when the connection from preparation material to in-class activities became too abstract to transfer. Or if activities were simply too difficult compared to the preparation material.
Regarding *difficulty*, positive responses pointed towards the importance of a clear structure, clear relations between homework and in-class teaching, and the overall description of the course vision. Consistency on these aspects lowered the risk of misinterpreting the actual difficulty level. Interestingly, students reported that a lack of structure made them estimate the course difficulty as either very easy or very difficult. But generally, if the transfer of preparation material content into in-class sessions appeared abstract or unclear, students typically perceived lectures to be very difficult. During such in-class sessions, students reported to request more step-by-step explanations and practical examples of homework application. High course difficulty was also related to lacking structure, especially when an exam assignment did not reflect the learning objectives that students experienced from either preparation material or in-class exercise sessions. Only the already flipped-experienced DAE course, was mentioned to appear balanced.
Students' *perceived learning outcome* was rated with a high learning outcome for coursework with clear structure, in-class processes that were well planned with clear goals, and which included the before-mentioned 'initiating coverage' of the homework preparation material in the opening phases of the in-class session, ensuring the perspective for students. When not in place, ratings were noticeably lower, which also including prior mentioned issues, such as when material or in-class sessions were too abstract, too high-level, without a clear purpose, or disconnected homework and in-class tasks. Interestingly, quite a few student responses included self-reports on moments where their learning outcome had suddenly increased dramatically, and that they did this at very different phases in the semester/course in question *and* through very different activities, with some students reporting that their epiphany occurred during a home-preparation session, while had it at an in-class activity, and some even only during the exam preparations.
Looking at the *integration of courses into the project*, the DAE course was the only course consistently represented in the project. When looking at ratings on the *overall project experience,* they suggest that while students found between-students groupwork quite satisfactory, this was less so with supervision and exams. Comments suggest that expectations may not have been sufficiently aligned, in terms of what the students expected the project / supervisor to need or result with. Prominent complaints from students in this regard focuses on the exam, and how supervisors were focusing a lot on the application of knowledge from the courses, in the project.
The last open-ended item; *students final recommendations*, focused in part on the *overall semester and course structure,* requesting clear and explicit relationships between courses and semester project. *Cross-course workshops* was highlighted as very useful for the integration of courses and project work. In relation to *semester planning and preparation*, the semester should be a well-planned, clearly structured 'whole'. This includes clear and transparent progressions through the courses, an overview of the entire semester, and better communication across courses, especially on assignments and increased workload phases, in order to avoid overlap. Students stated the need of developing a *consistent and logical flipped learning approach*, where all courses on the semester should apply a coherently similar approach. A clear *connection between homework preparation material and in-class activities* creates motivation to prepare, which can make the flipped classroom format work very well, and in fact increases learning. During in-class sessions, students besides valueing the

introductory in-class clarification, students also recommended using smaller, quicker assignments, possibly then in higher numbers, so tasks can be finished within the in-class session and utilize the format.

4 DISCUSSION AND CONCLUSION

There are some very central, interesting and useful tendencies in the data. While the students who expressed complete positivity with the whole flipped and integrated semester-initiative were in fact an overall minority, the issues brought up by the latter students are both logical and approachable for improvement. It also shows that implementing flipped learning is not simply about time-switching, but a craft in itself, that also very proficient teachers need to get familiar with over time. The issues with the flipped teaching approach, leaves the question of whether flipped learning is constructive for integration difficult to answer clearly. Integration suffered an underwhelmingly representation in the student responses, due to other matters that related to start-up difficulties for some teachers, in some phases of the semester. It therefore remains to be seen how well flipped learning can indeed become a catalyst for increased integration. Student responses were, however, always positive about course/project integration, both when it happened, and being discontent when it should have. Returning to the flipped learning, it appears that suboptimal application of flipped learning can have radiant consequences on students' perceptions of learning outcome and difficulty. This returns the focus to how flipped learning, with all its moving parts and possibly heavier self-study loads and requirements. It appears to be able to develop specific pressure points, where the approach *has* to deliver, to avoid students losing overview, perceiving the workload to increase, or lose their orientation of purpose or transfer of e.g. material into a meaningful application in another phase of the flipped cycle.

If anything, it could appear that flipped learning *needs* to have its methodological and pedagogical sweet spot established, to allow meaningful integration between courses and into the projects. Naturally, much of students' criticism was built on imbalances with semester coordination, course structures, flipped approach coherency, workload planning and met expectations.

It however is very interesting to see, how students independently reported when they suddenly hit a spot where their learning outcome was increased dramatically, because they finally understood the bigger picture. Observing the AP course, it consistently improved these aspects; structure, planning, in-class introductions, workload regulations, preparation material adaptation, etc. The course was gradually optimized during the semester, as the teachers became aware of the issues and solutions recommended by students, and certain students' feedback on when they started learning much more fits the timeline well.

Overall, there are still too much potential, and too concretely improvable solutions, to dismiss the idea of the flipped and integrated semester. Future iterations are bound to be facilitated, based on the experiences obtained in this initiating iteration. It is interesting, that students are suddenly requesting structure, vision, planning, coherency, etc., when faced with the flipped learning. One reflection of that relates exactly to the integration perspective. Future research will hopefully provide more concrete answer, but if one imagines that students actually started to care about the transfer, logic, academic and theme-oriented connectedness, because they now saw that it was theoretically possible; that is a nice motivator to continue the work.

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ENGINEERING STUDENTS' PREFERRED ROLES: ARE THEY STABLE, ARE THERE GENDER DIFFERENCES?

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ABSTRACT

Being able to situate oneself in an engineering role is a developmental process. Students may initially have idealized perceptions of a professional role and over time, they make this role more congruent with their own values and goals [1]. In light of this, Higher Education Institutions are being challenged to offer learning experiences and career exploration activities to enable students to clarify their interests, values and competencies in relation to a professional role [2]. This study compared the professional role preferences of more than 700 engineering students at TU Dublin (Ireland) and KU Leuven (Belgium). Professional role preference was measured with PREFER Explore, a personal preference test for engineers. The test aligns students to three professional roles for early career engineers: Product leadership (focus on radical innovation), Operational excellence (focus on process optimization) and Customer intimacy (focus on tailored solutions and customer satisfaction). A comparison was drawn between the role preference of first year students at TU Dublin and KU Leuven to establish if there were significant differences in preference across both universities. The results suggest that the role preference of engineering students does not shift from first to third year. There is also evidence that the PREFER Explore is sensitive to gender differences, with female students showing a greater preference for customer intimacy than males and males showing a greater preference for operational excellence than females at TU Dublin. The data have a number of implications for the labor market in Ireland and Belgium.

1. INTRODUCTION

Several studies showed that first-year engineering students lack clear views of their professional future and have rather vague ideas about engineering [3,4]. A 2018 study in KU Leuven (Belgium) and TU Delft (The Netherlands) indicated that first year students in both universities seemed to be most attracted to roles that involved product innovation [5]. However, in reality, only a small proportion of engineers are directly involved in technological innovation [6,7].

Being able to situate oneself in an engineering role is a developmental process. Students may initially have idealized perceptions of a professional role and over time, they make this role more congruent with their own values and goals [8]. In light of this, higher education institutions are being challenged to offer learning experiences and career exploration activities to enable students to clarify their interests, values and competencies in relation to a professional role [2]. Earlier studies have demonstrated that a better understanding of one's professional future and engineering identity not only has positive consequences for student learning and study choices [9,10], but also increases employability and job satisfaction [11,12]. This study sets out to explore the role preference of engineering students at TU Dublin and KU Leuven in order to address three research questions:

1) How does the role preference of engineering students at KU Leuven and TU Dublin compare?
2) Are there differences in role preference of first year engineering students based on gender?
3) Does year of study have any influence over this preference, or are the preferences stable?

2. BACKGROUND

2.1 Professional Role Model for Future Engineers (PREFER-model)

The PREFER-model was developed to enhance engineering students' reflection about their future selves. The model wanted to offer very concrete opportunities to grasp particular aspects of the complex and varying careers that an engineer can pursue that transcend the engineering discipline. The model represents three professional roles independent of discipline: Product leadership (focus on radical innovation & research and development); Operational excellence (focus on process optimization & increasing efficiency); Customer intimacy (focus on tailored solutions for specific clients). The roles specifically focus on early career engineers and are flexible in use since several roles can be combined in one job. The model has been thoroughly validated with both industry stakeholders and engineering students [13,14]. For each of the roles, essential non-technical competencies have been identified in close collaboration with industry [15].

Based on the PREFER-model, two tests were developed allowing students to explore their personal preference and to receive feedback on their role alignment and competencies. In this study, the PREFER Explore test was used to investigate role preference [16,17]. A further description of PREFER explore is provided in the method section.

2.2 The nature of interest

Interest is not a self-sufficient concept, it requires material, a subject matter and conditions on which an individual can operate, effort on the part of the individual and that the individual possesses some traits and tendencies that can be assessed [18]. So a researcher must consider the modality of the assessment of this interest and the nature of the interest as well. Interest can take on two forms, either *situational interest*, which is a snapshot of an individual's interests at a given time that can change based on their experiences, or *individual interest* which is relatively stable over time and has a tendency not to change with experience [19]. This highlights a question as to whether or not PREFER-Explore is a situational interest assessment or an individual interest assessment, which the authors will attempt to address during the discussion of the results.

2.3 Gender differences in vocational interest

The magnitude and variability of gender differences in individual preference was examined in great detail by Su, Rounds and Armstrong [20] who suggest that men and women differ in their preference for things and people, with women favoring people and men favoring things. Carrying out a meta-analysis of 503,188 responses to 47 interest evaluations, this gender difference in People-Thing orientation was found to be significant, with a large effect size (d = 0.93). While Su, Rounds and Armstrong concede that the application of some item development strategies can reduce gender differences, they suggest that interest may play a crucial role in occupational choices in STEM fields. This phenomenon was also investigated in an engineering specific context in a recent article by Bairaktarova and Pilotte [21]. In their study of 339 practicing engineers and engineering students, they found significant gender differences in both people and thing orientation in both practicing engineers and students.

3. METHODS

3.1 Data collection

In total the test was administered to 755 students, resulting in data from 624 males and 131 females being collected. A summary of the datasets is presented in table 3.1. All data collection was carried out with the full approval of the TU Dublin research ethics committee (REC 17-112) and the KU Leuven ethics committee (G- 2019 10 1792) respectively. The engineering discipline of the sample of students is provided in table 3.2, with first year students in both universities enrolled in a common entry route.

Table 3.1 Summary of data sets form TU Dublin & KU Leuven

University	Gender	N	Year of study	Year of collection	Collection method	Response type
TU Dublin	Female	12	1	2018	Pen and paper	Voluntary
	Male	98				
TU Dublin	Female	22	1	2019	Pen and paper	Voluntary
	Male	79				
KU Leuven	Female	27	3	2018	Pen and paper	Voluntary
	Male	127				
KU Leuven	Female	70	1	2019	Online platform	Obligatory
	Male	320				
Totals	**Female**	**131**				
	Male	**624**				
Grand Total		**755**				

Table 3.2 Engineering discipline of sample

Engineering discipline	N	%
Engineering (common entry)	596	79%
(Bio)Chemical Engineering	25	3%
Electronics-ICT Engineering	42	6%
Mechanical Engineering	81	11%
Structural Engineering	10	1%
BLANK	1	0%
Grand total	**755**	**100%**

This data allows a study using data from both universities to establish a comparative study of first years and the potential gender differences in the role preferences of first year students and moreover a cross sectional study in KU Leuven to evaluate if role preference was stable over time .

3.2 Instrument

The test instrument used in this research was PREFER-Explore [22] a 10 item personal preference test that aligns individuals to 3 professional roles based on their vocational interests. Product leadership, Operational Excellence and Customer Intimacy. Participants are provided with several questions, for example: You participate in an event that is aimed at stimulating knowledge sharing in your professional area. You can choose between different kinds of sessions. What sessions would you prefer the least and the most?

- Information meet ups and networking sessions with engineers from within your field
- Presentations on best practices to increase efficiency of production and delivery of services in your professional area
- Presentations discussing the state-of-the-art in your field of expertise

A maximum score of 10 and a minimum of -10 is assigned to each role, giving a theoretical range of 20. When students indicate a response is their least preferred, it deducts 1 point from that role and *vice versa* when they indicate it is their preferred role.

The test has been shown to be a reliable test for evaluating preference in each of the three roles with modest inter-item correlations and Cronbach's Alpha Coefficients ranging between .460 and .686 [17]. The items of PREFER-Explore are available at via the instructors test account on www.fet.kuleuven.be/prefer.

3.3 Data analysis

All data from each role were checked for normality to establish if the data were normally distributable or distribution free. A comparison was drawn between first year students in KU Leuven and in TU Dublin to establish if differences in role preference were observed across universities. As the sample sizes for first year students were different, homogeneity of variance was not assumed for the t test, this was confirmed with a Levene's F test. The null hypothesis H_{0a} was that there would be no difference in the sample means and an alternative hypothesis was promoted by the researchers that significant differences would be observed H_{1a}

Data collected from first year students were analyzed to establish if there were differences in role preference by gender using independent samples t-tests to compare the scores of male and female students in each of the three roles at both Universities. As the sample sizes for male and female students were different at each university, homogeneity of variance was not assumed for the t test, this was confirmed with a Levene's F test. The purpose of selecting first years for this analysis was to determine if there were differences in role preference by gender on entry to University. The null hypothesis was that no significant differences exist between the two cohorts H_{0b} and an alternative hypothesis was promoted by the researchers that significant differences in the sample means would be observed H_{1b} in each role. The purpose of this analysis was to determine if PREFER-Explore was sensitive to gender differences.

Using an independent samples t-test, the distribution of scores for each role were compared between first and third years students at KU Leuven to establish if they were significantly different from one another and to establish an effect size. As the sample sizes for first and third year students were different, homogeneity of variance was not assumed for the t test, this was confirmed with a Levene's F test. The null hypothesis H_{0c} was that there would be no difference in the sample means and an alternative hypothesis was promoted by the researchers that significant differences would be observed H_{1c}. The purpose of the analysis was to determine if the preferences of the students were stable over time.

4. RESULTS

4.1 Role preference by university

As highlighted in table 4.1, a strong preference for product leadership was observed in both universities, while operational excellence remains in a neutral position, followed by a lack of preference for customer intimacy based on mean scores.

Table 4.1. Independent samples t-test of scores from KU Leuven and TU Dublin

Role	University	N	Mean	Std. Dev	t	df	Sig. (2-tailed)	Cohens d
Product Leadership	KU Leuven	363	3.19	3.165	2.1	401	0.036*	0.185386
	TU Dublin	198	2.6	3.2				
Operational Excellence	KU Leuven	363	-0.06	3.788	-0.873	427	0.383	-0.07625
	TU Dublin	198	0.22	3.552				
Customer Intimacy	KU Leuven	363	-3.12	3.758	-1.272	411	0.204	-0.11017
	TU Dublin	198	-2.71	3.685				

*α = .05

It can be noted that first year students in KU Leuven hold a stronger preference for product leadership roles on average when compared with first year students in TU Dublin. Upon further examination, the difference in mean scores for product leadership were found to be significant, with a small effect size (.19), while no significant differences in the mean scores from the other two roles were observed across the two universities.

4.2 Role preference by gender

The analysis carried out on the sample of first year engineering students to determine gender differences in vocational interest revealed differential results in both universities. In TU Dublin no difference existed between female-male preferences for product leadership. For operational excellence and customer intimacy however, significant differences in female-male sample means were observed at a confidence interval of 95%. A subsequent examination of Cohen's d revealed a small effect size in both cases, with female students having stronger preference for customer intimacy than males and males having stronger preference for operational excellence than females. In KU Leuven, no significant gender differences were observed in the three roles.

Table 4.2 Independent samples t-test of gender differences in preference in TU Dublin

Role	Gender	N	Mean	Std. Dev	t	df	Sig. (2-tailed)	Cohen's d
Product Leadership	Female	35	2.66	3.067	0.129	52	0.898	0.025
	Male	163	2.58	3.237				
Operational Excellence	Female	35	-1.03	2.895	-2.674	59	0.01*	-0.459
	Male	163	0.48	3.63				
Customer Intimacy	Female	35	-1.46	3.551	2.282	51	0.027*	0.421
	Male	163	-2.98	3.668				

α = .05

Table 4.3 Independent samples t-test of gender differences in preference in KU Leuven

Role	Gender	N	Mean	Std. Dev	t	df	Sig. (2-tailed)	Cohen's d
Product Leadership	Female	68	2.91	3.398	-0.753	95	0.453	-0.088
	Male	295	3.25	3.112				
Operational Excellence	Female	68	-0.38	3.579	-0.804	106	0.423	0.069
	Male	295	0.01	3.836				
Customer Intimacy	Female	68	-2.53	3.846	1.422	98	0.158	-0.031
	Male	295	-3.26	3.73				

α = .05

4.3 Role preference by year of study

The analysis of the differences in role preference based on year of study at KU Leuven suggest that there are no significant differences between the role preference of first year students and third year students at a 95% confidence interval.

Table 4.4 Independent samples t-test of differences in scores by year of study

Role	Year	N	Mean	Std. Dev	t	df	Sig. (2-tailed)	Cohen's d
Product Leadership	First Year	294	3.25	3.117	1.237	216	0.217	0.135
	Third Year	128	2.8	3.532				
Operational Excellence	First Year	294	0.03	3.832	-0.657	238	0.512	-0.069
	Third Year	128	0.3	3.899				
Customer Intimacy	First Year	294	-3.28	3.724	-0.444	215	0.657	-0.047
	Third Year	128	-3.09	4.254				

*α = .05

5. DISCUSSION

The results of the comparison of role preference in KU Leuven and TU Dublin suggests that first year students, by and large, have similar preferences for each of the three professional roles, with the exception of Product Leadership, where the preference is significantly higher in KU Leuven than in TU Dublin, with a small effect size (.19). The reasons for this could be numerous, one possible explanation is that the economic activity of engineers in Belgium places a stronger emphasis on manufacture than Ireland, manufacture implies the production of a tangible product and may explain the greater degree of preference for such a role.

The results of the analysis of differences in mean scores by year of study reveal that students' role preference is rather stable. That would tentatively suggest that PREFER-Explore is an *individual* interest assessment as opposed to a *situational* interest assessment, as the results seem to be stable by year of study. Of course, the finding of this study are based on cross sectional data and so changes in preference could not be tracked. Previous research in Belgium suggests that role preference is not stable over time [14], however the sample sizes was low (n = 67) and the data were also cross sectional. On the basis of both the Belgian study and the study reported here, the author's hypothesis is that PREFER-Explore is in fact a *situational interest* assessment. To address this, a longitudinal study using PREFER-Explore would need to take place that tracked students' role preference over time. It would also be interesting to investigate whether students have clear preferences for a combination of roles. Earlier research with Masters students indicated that, when combining roles, up to 40% of the students expressed a preference, either as a single role or combination of roles, for customer intimacy [14].

The results of the analysis of gender differences in the mean scores on PREFER-Explore reveal differences in preference between male and female students in operational excellence and customer intimacy at TU Dublin. This would suggest that the test is sensitive, at least to some degree, to the female *people-orientation* discussed in the literature. The test did not detect gender differences in preference for product leadership however, this is contradictory to evidence in literature which suggests that male students are more *thing-oriented*. There are two explanatory factors, one is that the product leadership subscale is simply not sensitive to these differences and the second is that students who have selected engineering as their field of study are already predisposed to be *thing-oriented*, regardless of their gender. This latter factor is far less likely however, as confirmed by previous research into engineering students' people and thing orientation [20,21]. This first point, about the sensitivity of the test to gender differences is punctuated in the KU Leuven data, where students showed no difference in role preference based on gender in any of three roles, with a clear preference for product leadership being demonstrated from the data.

6. CONCLUSIONS

Nye et al [23] expected that interest would predict performance where that interest directly related to an occupation. In their study, which evaluated 60 years of interest research, the samples of students and those who were employed illustrated moderate correlations with performance criteria and persistence at work and in school highlighting the benefits of interest assessment in predicting job success. In addition, they discuss the added benefit of providing interest profiles rather than interest levels stating that in predicting performance in a particular occupation or major should involve considering the interest profile in that particular context. Learning the knowledge and skills required to understand topics where there are less well-developed interests is a difficult task. Students are less motivated to work on developing knowledge about these topics. Their ability to make enquiries about these topics is also limited, questions tend to be procedural, unless they set a goal to learn about it. Most adults can set goals and utilize motivational strategies from other content domains in order to master content in less well developed interests, and they can learn to do so [24]. It is an imperative then, that students can frame the topics of study in their programme within a professional role, to enable them to develop motivational strategies to succeed in topics where they lack an intrinsic motivation to succeed.

In addition, and in response to previous work by the authors on role preference in different universities, a comparison was drawn between the interests of first year engineering students at KU Leuven and TU Dublin to evaluate if there were differences in role preference across these universities. As noted in previous research, there is a strong lack of preference for customer intimacy roles and a strong preference for product leadership roles. Despite female students having a stronger preference for customer intimacy, the mean scores on this subscale still range from -1.46 to -3.26. With approximately 3.5 standard deviations from the mean score on this role, even positive scores for customer intimacy are relatively small compared to the other two roles. This presents a number of challenges in Ireland and Belgium, as traditional manufacturing begins to decline and jobs in professional services continue to grow [25,26] the role of an engineer in industry is changing. There are two key issues, the main issue being that if we concede that engineering is as much about people as it is about product and process, a question is raised about how we can attract talent to engineering that focuses on the former of these roles as well as the latter two. There is a second, paradoxical issue, in that female students at TU Dublin have a stronger preference for customer intimacy roles than males, roles which are becoming more and more important to the industry, yet females remain consistently underrepresented in traditional engineering disciplines. The authors argue that in light of this research, now more than ever, initiatives seeking to secure the STEM pipeline are essential to ensure we avoid vertical skill mismatch in the field.

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ARE FINNISH COMPANIES READY FOR ONLINE CORPORATE LEARNING?

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ABSTRACT

The integration of digital technologies and the trend of life-long learning impact on corporate learning. Companies no longer want to build their own training departments and centers, they are looking for opportunities and resources outside. University and industry are building grounds for mutual benefits. This study aims to reveal preferable forms of education and training in the corporate sector in Finland. The study is based on a survey of 32 industrial companies. It addresses the current state of corporate learning in Finland. The results reveal that the majority have already integrated corporate training through external sources. Finnish companies prefer internal face-to-face training.

1 INTRODUCTION

Digitalisation embraces different sectors of our life including education. There are two niches in education and life-long learning: academic and corporate learning. Corporate training research is limited in the scientific literature, therefore present a special interest. In addition, the background for this research is Erasmus+ Capacity Building Project CEPHEI [1]. The project aims to increase collaboration between industry and university on the ground of a joint online learning program. As a result of the work, the learning platform was created in a consortium of 9 universities with courses in blended and online forms. Each course is a result of university-industry cooperation. The industry participation differs for each course. Courses are designed with the problems brought from industry or aimed to teach industry. Therefore, the study related to

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corporate learning is specifically crucial to industry involvement, building joint learning programs and future sustainable cooperation.

This study focuses on the corporate sector and analyses the existing forms of learning and training. The primary two core options of training are analysed: external and internal.

1.1 E-learning

Digital technologies are changing the educational paradigm and enable cooperation between different organizations. The vast amount of digital teaching materials allows opening the learning environment [2]. The growing number of higher education institutions (HEIs) transits their courses to digital form. The world's top-ranked universities have extended their learning environment and offer online courses and degrees in various Massive Online Open Course (MOOC) platforms. Finnish HEIs also apply the “go online” strategy and launch online campuses and non-degree online studies.

The Industry-University collaboration brings significant benefits for both sides. University can involve more real cases and problems to solve for their students and provide the link for the future work placement between industry and university. The updated learning process prepares students for future challenges during their work life. From the other side, companies can hire the students using the analytics of the existing joint learning management system. In addition, companies can use university courses as training for their employees.

1.2 Corporate learning

Over four million students of all levels annually graduate from European universities [2]. Most of them start their career and continue education through the corporate system, training and lifelong learning. Corporate education is a branch of the educational system, but it pursues different goals than traditional higher education. The objective of corporate learning is to change the mindset of employees and ensure that they have knowledge and skills to undertake specific tasks [4]. The specific characteristics of corporate education are fast pace, career-oriented, benefit to the company.

Masalimova and Sabirova (2014) have analysed socioeconomic and educational literature and provided a holistic classification of corporate learning. According to local characteristics, the training can be in-house (carried out within the company) and out-of-house (courses, workshops, seminars conducted on third party territory). The key decisive factor whether to outsource or conduct training internally is the availability of financial, time and human resources [6]. According to Masalimova et. al (2016), European companies (based on data from France and the UK) prefer in-house training. The study of the Finnish market shows that different size companies are equally invested in employee training, but forms of training are not specified [8]. Thus,

the first hypothesis to test in this study is: Finnish companies alike other studied European companies prefer internal corporate training.

Corporate education is happening in both traditional and digital forms. Corporate learning is one of the fastest-growing segments of the e-learning market: 51% of European companies are offering online opportunities to learn to employees [4]. Thus, the second hypothesis of this study is: Finnish companies prefer online corporate training.

2 METHODOLOGY

2.1 Research design

The research aims to identify preferred forms of corporate training among Finnish industrial companies, and whether they depend on the size of organization. The study utilizes a questionnaire survey as it is an objective way to test research hypotheses. Ensuring the reliability of results, the questionnaire adopts Crumpton (2011) and Masalimova et. al (2016) studies. The questionnaire was designed both in English and Finnish. To ensure the identity of questions in both languages it was translated by two people and then compared.

The questionnaire includes an introduction, where the objectives of the research are explained. Later, respondents are asked about company size and availability of corporate education. The last part invites respondents to rate on a five-point Likert scale which forms of corporate training are most commonly used in the company.

2.2 Sampling and data collection

List of possibly suitable companies was acquired in Technology Industries of Finland Association. Initially, it included 1400 companies, the repeating and international companies were excluded from the list. Out of 1161 companies, 20% were randomly chosen due to high time consumption for contact data collection. The target group of the survey is management.

Link to the survey was distributed via email. Out of 232 emails, 204 were delivered. The reminder was sent to potential respondents within a week. 32 answers were submitted to the questionnaire, thus, the questionnaire was completed with an effective response rate equal to 15,6%.

3 RESULTS AND DISCUSSION

The collected data was encoded and analyzed with data analysis and statistical software STATA SE16. The use of English and Finnish version of the questionnaire was justified as 53% of respondents preferred Finnish. Two out of 32 respondents stated that there is no corporate training in their company. The majority of respondents (50%) are from medium-size companies, small and large companies were equally represented. The descriptive statistics of factors is presented in Table 1, where 1

means this form of corporate training is not used at all, 5 is the main form of corporate training.

Table 1. Descriptive statistics of factors

Variable	Mean	SD	Min	Max
Internal face-to-face training (organized by HR or training department)	3,438	1,134	1	5
External face-to-face training (conducted by an expert or influencer from outside of your company)	2,812	1,203	1	5
Internal online training (organized by HR or training department)	2,5	1,391	1	5
External online training developed by university for the needs of your company	1,219	0,491	1	3
External online training developed by an expert/influencer/other company for the needs of your company	2,563	1,076	1	5
External online training at massive online open courses (MOOCs), f.e. Coursera, Udemy, LinkedIn	2,563	1,318	1	5

The respondents evaluated "internal face-to-face training" (M=3,438) higher than any other option, that means this form is used more often. The one-way ANOVA analysis was conducted in order to identify if the decision to invest in corporate training depends on the company size. The results are presented in Table 2.

Table 2. ANOVA analysis of variance

	Sum of squares	Mean square	F value	P-value
Between groups	0,0625	0,03125	0,50	0,6117
Within groups	1,8125	0,0625		
Total	1,875	0,06048		

According to results, p-value=0,6117, there is no statistically significant difference in the decision to have corporate training between different sizes of companies. The result corresponds with the findings of Organization of Economic Co-operation and Development (2015) that Finnish enterprises of all sizes equally invest in employees training.

The channels of corporate education can be classified at the number of bases, however, this research focuses on classification by location and instruments used for delivery. Aiming to compare preferred forms of corporate training, the existing variables were divided into four groups: internal corporate training, external corporate training, face-to-face corporate training and online corporate training. T-test was conducted to find whether there is a relationship between pairs of variables.

According to t-test, there is statistically significant difference (p-value=0,0009) in mean values across respondents for variables internal (M=2,97; SD=0,95) and external (M=2,29; SD=0,6) corporate training. The hypothesis that Finnish companies alike

French and UK companies prefer internal training is approved. Even though in-house training requires more resources, it allows companies to keep sensitive information.

According to results of t-test, there is statistically significant difference (p-value=0,0000) in mean values across respondents for variables traditional (M=3,13; SD=0,90) and online (M=2,21; SD=0,65) corporate training. Vernau and Hauptmann (2014) state that European companies tend to offer online learning, however, the hypothesis that Finnish companies prefer online corporate training is declined.

There are several limitations associated with this study. Firstly, the questionnaire was distributed among Finnish industrial companies, thus, the results cannot be generalized to the whole Finnish market. Secondly, bigger sample size will allow analyzing the data deeper, for instance, conduct cluster analysis.

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UNDERSTANDINGS OF 'GLOBAL RESPONSIBILITY' EXPRESSED BY CIVIL ENGINEERS WORKING IN LONDON

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ABSTRACT

This paper discusses the term 'global responsibility', how it emerged and why, and analysis of interview data collected from nine civil engineers working in London regarding their understandings of the term. Professional Bodies often take the lead in envisioning change, by identifying the direction their professionals should take to help address society's evolving needs and aspirations. Often, such Bodies charge academia with addressing society's evolving needs through research, outreach, and preparing the next generation of professionals. In the UK, leaders in civil engineering have pressed for individual and collective action to facilitate sustainable development and decrease occurrence of corruption. Nevertheless, under the current model of professional conduct, finances (typically the extractive side of the economic pillar) continue to take precedence over the environmental and social pillars. In response, the United Nations has encouraged use of the term 'global responsibility' to expand public perceptions of what quality life should entail. This paper represents a first step in comparing how common use of the term in UK civil engineering compares to its

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originally intended meaning, and what London-based engineers are doing to facilitate it.

1. INTRODUCTION

In the UK, leaders of Professional Bodies in civil engineering [1] [2] have pressed for individual and collective action to facilitate sustainable development and decrease occurrence of corruption [3], which had become particularly evident in large-scale infrastructure projects. According to the Brundtland commission [4], "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development implies concern for environmental and social sustainability as well as financial aspects, as conveyed in the three pillars (environment, society, economy) that should be given balanced consideration in decision-making. Nevertheless, financial profit has tended to be the focus of the business model within which civil engineering typical operates, and it relies heavily on indicators like Gross Domestic Product that are extractive rather than generative or re-generative in nature [5]. Many civil engineers have called for more holistic visions of success.

The United Nations has encouraged use of the term ‘global responsibility’ to expand public perceptions of what quality life should entail. The specific term has not gained a wide footing, however, and seldom appears in literature on civil engineering. Despite not using the term, Professional Bodies in engineering have increased their attention to various dimensions of global responsibility, further codifying ethics, sustainability, and sustainability development and frequently highlighting and promoting cases for educators and practitioners to use as precedents [6]. Engineering Professional Bodies also have looked to higher education institutions (HEIs), asking them to equip emerging graduates with the skills and abilities necessary to enact global responsibility and incorporating such aspects into conditions for accreditation.

Considering the UK specifically, Professional Bodies provide grants, guides and frameworks, and other forms of support to HEIs to help them teach ethics and sustainability [6]. They provide continuing professional development (CPD) activities to help members develop new knowledge and skills, they require early-career engineers to engage with some dimensions of global responsibility in order to become Chartered, and have recently enacted requirements for Chartered engineers to maintain portfolios of CPD.

In this study, we interviewed nine civil engineers who work in London, asking about decisions they had made recently related to ‘global responsibility’ and, subsequently, asking them to define the term for us. In this paper, we report how they define the term—assessing to what degree this aligns with the United Nations’ definition—and we identify what this implies for higher education and ongoing professional development.

1.1 Existing definitions

Kung published a seminal book on the topic in 1991, called published *Global responsibility: In search of a new world ethic* which promoted "Planetary Responsibility" as the slogan for the future, encouraging "an ethic of responsibility in place of an ethic of success or disposition". This new ethic would encompass "responsibility for our neighbours, the environment and the world after us" and would define "ethics as a public concern" [7, p. viii].
In 2005 the United Nations, in collaboration with companies and business schools, launched a Globally Responsible Leadership Initiative (GRLI) "to catalyse the development of globally responsible leadership and practice in organisations and societies worldwide" [8, footer] and facilitate "deep systemic change across three domains: how we live and make a living, how we learn, and how we lead" [8, ¶1]. Despite efforts to promote a holistic vision, the most commonly-cited aspect appears to be Corporate Social Responsibility (CSR), which Chen and Scott [9] describe as corporate citizenship and as "a self-regulating business model that helps a company be socially accountable—to itself, its stakeholders, and the public" (¶1). They do so by "operating in ways that enhance society and the environment, instead of contributing negatively to them" (¶2). Related to education, the European Federation of National Engineering Associations (FEANI) aims to strengthen "the position, role and responsibility of engineers in society" (p.42) and has mentioned the term 'global responsibility' in its newsletter [10]. Nevertheless, the term does not commonly appear in engineering literature and appears to be more commonly mentioned in Europe than other English-language areas of the world.

2. METHODOLOGY

This project uses thematic analysis alongside grounded theory [11] to "perform a simple and preliminary study of an area where there is little previous research" [12, p.156], in this case regarding to the emergence of the term 'global responsibility'. Thematic analysis using grounded theory has proven to be highly effective for this type of exploratory research [11]. Consistent with this methodology, semi-structured interviews with open-ended questions were conducted to assess how participants experienced or perceived the topic [13]. The study was designed to find out how participants themselves defined, in their own words, 'global responsibility' and was approved by UCL Ethics. This exploratory study was conducted by a team of engineering education researchers at the request of Engineers without Borders UK (EWB-UK), who defined the topic, sample size, and scope of work. Sampling was pragmatic and purposeful. The nine interview participants were recruited by EWB-UK and included three women and six men (see Table 1 for demographic information). EWB-UK solicited participants via email, newsletters, Tweets, and a webpage explaining this "Research looks into global responsibility in engineering" and "aims to understand whether and how global responsibility impacts on decision in the engineering profession". A schedule of interview questions was prepared and applied in a conversational, semi-structured way.

Table 1. Participant Demographics

	Sex	Grad. Date	Degrees Held	Prof. Years	Employment Sector (Type of Work)	Charter Status
P1	F	2016	M.A. & M.Sc. (Sustainable Development)	3-5	Sustainable Development (Consulting & Research)	N/A (Ph.D. Under-way)
P7	F	2015	M.Eng. (Civil & Environmental Engineering)	3-5	Structural Engineering (Infrastructure & Building Design)	Underway
P8	M	2014	M.Eng. (Civil & Architectural Engineering)	3-5	Structural Engineering (Building Design)	Chartered
P3	F	2014	M.Eng. (Civil Engineering)	3-5	Structural Engineering (Building Design)	Underway
P9	M	2012	M.Eng. (Civil & Structural Engineering)	5-10	Rail (Design Management)	Chartered
P4	M	2010	M.Eng. (Civil & Structural Engineering)	5-10	Structural Engineering (Infrastructure Design)	Chartered
P6	M	2010	M.Eng. (Civil Engineering)	5-10	Rail (Infrastructure Construction Planning)	Underway
P5	M	2006	B.Sc. (Geoscience)	10-15	Ground Engineering (Construction Costing)	Chartered
P2	M	1982	M.A. & M.Sc. (Civil Engineering)	30-35	Rail (Design Management)	Chartered

One-hour semi-structured interviews with open-ended questions were conducted, professionally transcribed, and then verified for accuracy by the research team. Open, axial, and selective coding were used to determine themes and categories and analyze data. Weekly peer-debriefings were held with core research team. In addition, an expert Advisory Panel coordinated by EWB provided guidance throughout the process.

3. RESULTS

Participants provided a solid understanding of typical concerns and experiences working in civil engineering in London. The open-ended nature of the questions allowed participants to raise any topics that came to mind.

3.1 Initial thoughts on 'global responsibility'

Mentions related to the environmental pillar were more frequent than mentions of the social pillar or the sub-set of ethics and anti-corruption, which often surfaced only with prompting from the interviewer. When asked about 'global responsibility', most of these nine engineers:

- indicated it's an ambiguous term and asked for our definition;
- used the Brundtland Commission's words (longevity, future generations) to describe the concept;
- explicitly referenced the three pillars (social, economic, environmental).

Most participants arrived at the interview expecting to discuss topics related to EWB but indicating they were not familiar with the term 'global responsibility', *per se*.

> *P4: When I knew this was like an Engineers Without Borders type [activity], I thought it was maybe about international development type definition of global*

responsibility. But then, actually, in terms of what my work is, the global responsibility is about understanding social implications of engineering, of the work we do—and that can be wherever it is in the world.

Interview data revealed that, to these civil engineers, 'global responsibility' is nebulous, ambiguous, and multi-layered term. Although these specific words were not seen as a familiar grouping, all participants did associated the term with the three pillars—environmental, social, and economic.

P9: how many times have I heard the term global responsibility? Not loads. (…) I think in my eyes, its closely linked to sustainability, which is three pronged with environmental, social and financial. And by acting sustainably—considering all three of those branches—I think you are fulfilling a global—. You are thinking about global responsibility. But (…) to me, it's not a buzz word, in the industry. Where did I hear about it? Through perhaps some industry materials. But I don't know. In my eyes, it's not something which you hear loads.

Nearly all participants discussed it in terms of considering impacts their decisions have on future generations as per The Brundtland report [4]:

P2: You go into civil engineering because you're building for the future generations. You're not going in there to mortgage it for the future.

Yet, most also admit they typically focus on environmental aspects in their efforts to be responsible:

P6: I see it as quite tied towards the environment, which it probably isn't. I'm sure there's social aspects, and probably economic aspects, as well. But (…) I'm aware probably through other part-time work I've had, there is a big drive with multinational companies about 'global corporate responsibility' which links into charity work of all kinds. That's a separate issue, really, to me, so my understanding of global responsibility links quite closely to environmental sustainability.

P9: I find it, an almost all-encompassing term. Like you've literally had a positive influence on every person on the planet (…) I find it very hard to really pinpoint how one has contributed towards global responsibility (…) Sustainability, on the other hand doesn't have that (…). I now have the liberty to specify, as I said earlier on, the materials, or any replacements of materials, which could have an environmentally positive impact.

Whereas others quite naturally incorporated social considerations, with understanding of their own vantage point and inherent biases:

P7: I guess I live in a Western world and I have Western views, like I say about equality, and specifically things about the Sustainable Development Goals. I think there's a lot under global responsibility that you could filter down into those goals, but essentially, traditionally, it came under environmental politics and there's three pillars in there—environmental, economic, and social? I guess this is what I'm trying to say is this is kind of social side which probably stretches the traditional view of environment. Yes, that's how I related it to global responsibility.

3.2 Definitions of 'global responsibility'

The interviewers resisted providing any *a priori* definition, but instead started the interview by asking participants to discuss "an instance in your recent work as a civil engineer where you made decisions related to 'global responsibility'" and then, at the end of each interview, asking participants to summarize their definition of the term. Answers at this point resembled the following:

P3: I think I would fall back on the definition of sustainability and I would say that it's making sure that we don't compromise the future generations' needs, on a global scale, or on a small scale, really, by the needs of today. So, it's making sure that we're not using things irresponsibly now, that will hinder the future generations. I think that's how I would define it.

They often see this with regard to infrastructure projects:

P5: Within civil engineering, I would say it's carrying out projects, creating infrastructure, without having a detrimental effect—a lasting detrimental effect—and minimizing that effect on the world.

P8: I would define "global responsibility" as minimizing the negative externalities of your work. Again, whatever they may be, because a lot of my work will have—. In a global impact sense, the main impact that I will have is climate change, so carbon and embodied carbon, as an example. Looking slightly lower then, they'll be on to supply chain, logistics and procurement. Then, other bits will be on the local environment, literally where they build the building and what impact of that is. A global impact to me has, it covers everything from very local impacts, because this space now, for a person to use, it has an impact on the people around it and the society around it up to, yes, this will impact the entire plan.

In addition to mitigating negatives, they seek to stress positives:

P8: I said global responsibility is minimizing those negative impacts. And I guess, conversely, maximizing the positive outcomes. But that's sometimes harder to point to. You can say, "I'll save carbon." It's hard to point that your good resource stewardship has resulted in—.

P9: It would be making conscious decisions, conscious decisions, about actions you're going to take, that will have a positive impact on society, and on the planet in terms of sustainability and its longevity.

P4: Engineering and international development is about providing maybe a facility or a place for learning or something that people can use in the future rather than building for the sake of it. And social implications of large engineering schemes in developed countries is about how people use and what's going to happen after you've finished building this building.

Several saw inclusivity and diversity as crucial elements:

P2: I think it is a global responsibility to look at all users.

They had differing views on how individual and collective the actions should be.

P1: I think that the word global in this responsibility means a collective responsibility.

P7: global responsibility (…) has a variety of scales. And the fact that you use the word 'global' insinuates that, "Do I as an individual living and working in London, have a responsibility to deliver something, or work in a way that takes the overall globe into account?" And I guess, yes.

Being globally responsible has both collective and individual components:

*P7: For me, is a very personal, individual thing. I don't feel like it comes from a collective. And I feel like dealing with global issues that come under the 'global responsibility' umbrella are *dealt with* by the power of the team, the power of the*

group, united vision, united thoughts and united strategy on these things. I think that's how things change. But when it comes to global responsibility, I feel like it comes from a place within. And where your ethics lie, and where your interests lie. And how aware you are, through your own personal experiences and upbringing, of some of the many problems that face society.

Unlike the engineer quoted above, most participants did not inherently associate 'global responsibility' with ethics and anti-corruption, but discussed the topic when prompted:

P3: I suppose my observations of corruption don't necessarily—maybe it's me being naïve—they don't necessarily link to global responsibilities, as such.

P6: Yes, so the ICE [Institution of Civil Engineers] themselves have a Code of Conduct which will be linked to various things we discussed, so sustainability and sustainable development, has its own objective as well as two separate, but abiding by the Codes of Conduct which probably do cover corruption.

Some participants identified a connection to public health, safety, and welfare:

P8: health and safety (…) is always on the core ones in structural engineering. In the global sense you don't sense you don't your building to fall down! But, also then again, we try to make sure it's constructible. We're not injuring people. We're not using harmful materials. There's always a lot of—from asbestos, right down to just chemicals and paints and things. (…) There's the hierarchy of needs. Ultimately, we need a safe building and then below that you need to be safe to construct.

Mentions of job-site health and safety were more frequent:

P5: in my experience, it's the large infrastructure jobs which focus more on quality, environmental, and health and safety. (…) Health and safety is extremely good in this country. And can be very poor in other countries. Constructing safely is often extremely slow, and extremely expensive.

The barriers sometimes feel palpable and overwhelming. They consider what they can achieve:

P1: I think there's many layers to it [global responsibility]. And, then you can take it to pieces and then try to sub-define that in different domains, in different professions, what this responsibility might mean, what are your limitations, what would you be capable of achieving? [...] The more you start to be conscious about this, the more you realize the amazing amount of barriers you are going to be encountering.

The scope of decision they are allowed to make presents a core limitation. An early-career engineer noted his limited sphere of influence but explained this should grow over time:

P6: I focus quite heavily on sustainable development of the built environment. I think you get quite, quite skewed, by your profession. I probably think of it: I think I have a global responsibility as an engineer, I have a slightly different global responsibilities as a human. I can't really describe ways in which how that perhaps an easier way to affect the outcome. It's become probably ever more apparent, isn't it, with the media coverage of things. Some people suggest we should stop eating meat, that that's the best thing we could do. But then as an engineer, we just think about the built environment we live in.

Some participants found peace in identifying opportunities for improvement:

P2: in sustainable development, you're always looking for ways in which people have built sustainability into the designs of what they do quite often with carbon footprint, so what material we use did you think of, et cetera, et cetera, et cetera. Should always be part of the way civil engineers thinking.

Although participants spoke at length about the limited scope of their own day-to-day work, they also identified aspects of global responsibility that they do have the purview and ability to affect.

P6: I can only really work in my globe which, obviously, how many millions of times smaller than that—the actual planet. I can only really affect things in my sphere. I think that's probably the practicality of being an engineer coming out. I'm limited by what I can affect. As my career develops, maybe there's scope to think that I will increase. Get in charge of perhaps a whole project, a framework of projects, or something like this. Depending on my position within an organization.

3.3 Mentions to environmental, social, ethics and corruption topics

Table 2 provides frequency counts regarding how many participants mentioned various aspects of the environment.

Table 2. Frequency of environmental mentions

Environmental topic	Participants	Mentions
Materials	8	89
Carbon or climate	8	49
Water	6	41
Site or land	6	19
Retrofit	4	14
Pollution	4	10
Logistics	3	14
Resourcing	4	7
Electric power	2	8

Table 3 identifies how many participants discussed each social topic and the number of times the topic was mentioned during the interviews. Although the research team initially considered health and safety to be a social topic, participants had repeatedly raised it when asked about ethics, and therefore the team chose to report both job-site health and safety, and public health and safety in Table 3.

Table 3. Frequency of social mentions

Social topic	Participants	Mentions
Community	7	56
Access	7	44
Longevity / future generations	5	46
Developing nations	4	21
Gender and diversity	4	13
Efficiency having social benefit	4	6

Table 4 identifies the number of participants who discussed each category related to ethics and indicates who brought each of these topics forward. Six of nine participants associated on-site Health and Safety with 'global responsibility' without any prompting from the interviewer. However, most participants did not inherently link 'ethics' and 'anti-corruption' activities to the term.

Table 4. Frequency of ethics and corruptions mentions

Ethics topic	Participants	Mentions
Participant-identified topics		
Occupational health & safety	6	19 relevant passages with 26 mentions of safety
Public health & safety	3	15 relevant passages; 19 mentions of safety
Advisor-identified topics		
Ethics	2 unprompted, 9 total	14 mentions of the word by participants
Corruption	1 unprompted, 4 total	8 mentions of the word by participants
Bribery	0 unprompted, 3 total	2 explicitly, 1 implicitly through description

Overall, it is in the selection of materials, planning for efficient use of resources, use and development of new technologies and in pushing back against poor decisions that they described their best opportunities for facilitating change. For these engineers, infrastructure projects are seen as having the greatest ability to influence both social and environmental sustainability.

> *P4: I suppose that—main sort of global responsibility thing—is considering sustainability in everything we're doing. So, I'm working on a big infrastructure project at the moment and there's a lot of consideration about minimizing the direct ways that we can influence sustainability as engineers, which is minimizing the material which we use, and minimizing the harm of the materials, we're using. That's sort of thought as part of a global problem that we need to, it's not isolated it's your project, it's a global issue, that you are having to consider.*

Such projects allow the engineers greater flexibility in addressing social needs than smaller scale projects for profit-driven clients.

> *P4: in terms of what my work is [designing infrastructure projects for mostly private clients], the global responsibility is about understanding social implications of engineering, of the work we do, and that can be wherever it is in the world.*

SUMMARY

Based on the narratives provided by these nine civil engineers, we can confidently state that:

- some specific environmental topics (e.g., material selection, carbon emissions) are of central concern in day-to-day work.
- the sample group had a collective sense that global responsibility involves protecting future generations and working toward environmental and social stability.
- the sample group is able to identify aspects of global responsibility that the projects they work on affect.

Concern has been growing for how to teach these subjects and how to infuse industry with new knowledge and skills that reflect values of global responsibility. "This new view that engineers will have of themselves will require new knowledge and skills" asserted Fuchs and Bochar [11, p. 44], emphasizing that changes have "to be made to engineering-study-programmes, as these are the primary resource for

attaining new knowledge and expertise". As leaders of FEANI, Fuchs and Bochar [11, pp. 44-45] insist:

> *[engineers] can no longer limit ourselves to addressing technical issues as we did in the industrial age. Instead, we need to take a holistic view of the economic, ecological and social impacts of our actions—and always do so from a global perspective. Our objective here must be to ensure that every engineer adopts an international point of view so as to enable him or her to contribute to the improvement of the quality of life for everyone on the planet. Such "holistic expertise" will enable engineers to think and learn in an interdisciplinary manner and develop products that address the social and global challenges we face.*

Based on the interviews we conducted, it appears that civil engineers in London (those who would volunteer an interview on global responsibility at the request of EWB-UK) do recognize the facets of the term intended by developers of the term. They do not, however, naturally describe 'ethics' as a specific subset of sustainability as it has been categorized in the past decades by professional engineering organizations. Interestingly, the new Demonstrated Ability requirements posed by American Society of Civil Engineers (ASCE) Committee on Education [14] have pulled ethics out, making it a distinct category that now falls beside—rather than within or sub-set to—sustainability. Moreover, the Committee has recommended that the medium and higher levels of ethics (with regard to Bloom's Taxonomy) be demonstrated in practice, via structured mentorship, as they are more advanced than could be demonstrated at the undergraduate level of university.

In other papers, our research team will identify the challenges that these engineers described facing in their attempts to enact global responsibility and discuss more about what this implies for higher education and professional development of engineers in the UK.

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PROFESSIONAL PRACTICE IN ENGINEERING EDUCATION: LESSONS LEARNED FROM STUDENTS PARTICIPATING IN INTERNSHIPS

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Conference Key Areas*: Interdisciplinary engineering education, linking different disciplines both inside and outside engineering, linking with society. Engineering curriculum design, challenge-based education, maker projects, use of professional tools.*
Keywords*: Experiential Learning, Internships, Communication, Collaboration*

ABSTRACT

This research paper explores the experiences of undergraduate engineering students who completed internships as part of their academic program. Engineering programs are required to fulfil industry needs and prepare students to develop the competencies required in the workforce. We used a qualitative study design to investigate the engineering students' experiences doing internships in the United States. Data were collected using semi-structured interviews and the interview protocol was informed by the boundary-spanning framework. Results report the different aspects of the internship that students found valuable, and the most salient topics were their boundary spanning role, coordination and communication, knowledge and learning, problems and preparation.

INTRODUCTION

1.1 Background

The engineering field has evolved considerably in the last decades. Engineers are required to have the knowledge and competencies to solve contemporary problems and have a positive societal and economic impact. Hence, engineering schools are required to develop engineering graduates that have the competencies that are required by the engineering workforce and in the professional societies and accreditation entities. However, engineering graduates are faced with challenges of entering a completely new environment [1]. Part of the problem is the lack of opportunities in the classroom to replicate industry-like experiences. Nevertheless, research suggests that experiential learning can provide some of those opportunities [2]–[4], more specifically, professional internships provide one of the most significant learning opportunities for students [2], [5]–[8]. Hence, Universities have been promoting internship opportunities for engineering students, some Engineering Schools in some countries even have mandatory internship programs. However, there is not much research conducted on the value that internships bring to engineering students.

The purpose of this paper is to understand engineering students' perceptions of the value of their internship experience. Specifically, we want to answer the following research questions:

1. What are the perceptions engineering students have about their internship experience?

In this paper, we report preliminary results from interviews conducted with engineering students after having an internship experience.

1.2 Theoretical framework

In this study, we used the Boundary Spanning framework [9] that provides a unique lens to understand the realities of engineering work as experienced by practicing engineers. The framework fully unpacks aspects of working with people within an engineering organization: including classification of types of boundaries (cultural, educational, demographics, job role, organizational) and boundary spanning activities (managing information, coordinating, networking, representing and influencing). We selected this framework because we wanted to identify students' different interactions when working in a professional environment and how those interactions influenced their internship experience. In addition, our work is framed by the American Board of Accreditation and Technology (ABET) criteria [10] who developed expected abilities, skills, values, and attitudes that must be demonstrated by engineers at the point of entry to the engineering practice. The integration of the dimensions of the two aforementioned frameworks provided a solid underpinning for the study since we were able not only to understand how well the competencies that are required for engineering students in the U.S. are present when working as a student in a professional experience but also how the different interactions and roles students had shaped the experiential learning opportunity.

2 METHODOLOGY

The purpose of this study is to understand students' experiences doing internships. Since our primary objective is to understand students' experiences qualitative methods that provide rich descriptions are appropriate [11]–[13]. Qualitative research is based on the examination of a phenomenon by using data directly from the participants that experience it [18], based on the examination of the context and complexity of the real-world setting of the phenomenon in order to have an integral understanding of it [14], [15]. We conducted semi-structured interviews with engineering students after participating in an internship experience. Interviews were conducted online and in person and were audio-recorded. The total duration was approximately one hour, and students signed a consent form to participate. The recordings were then transcribed using an online software. To ensure confidentiality, the transcription was cleaned by using pseudonyms and identifiable data was removed. The study secured ethical clearance. Participants were engineering students at a Research University in the United States that had participated in an internship. Table 1 provides more information on the demographics of the participants including the details of the participants' internship roles and company type.

Table 1. Participants' information

#	Engineering program	Gender	Ethnicity	Role	Company Type
P1	Industrial and Systems Engineering	Female	African American (Black)	Industrial Engineering Intern	Aerospace Industry
P2	Industrial and Systems Engineering	Female	White	Materials and Production Intern	Power and Energy Industry
P3	Chemical Engineering	Female	White	Production Services Engineer	Manufacturing Industry
P4	Aerospace Engineering	Female	White	Engineering Co-Op	Defense Industry
P5	Computer Engineering	Male	White	Software Engineer	Aerospace Industry

Data were analyzed by three researchers using an open coding approach [16] there were several rounds of team discussions where the researchers discussed an initial codebook and in the second data analysis round inter-rater reliability tests were conducted to identify reliability of the coding process [16]. The process was conducted using the DEDOOSE qualitative software. In cases where there was disagreement about codes, discussions were hold until agreement was reached.

3 RESULTS

From our analysis, several key patterns emerged across the participants' qualitative responses on their internship experiences. There was a total of 361 excerpts coded from the interview data, and the following themes were the most prevalent among the participants:

3.1 Boundary Spanning

Most of the participants agreed that they were involved as 'boundary spanners' who have linked or connected with others across three types of boundaries during their internship experience, including intra-team boundaries, inter-organizational boundaries, and hierarchical boundaries. Participants in the interview frequently discussed how boundary spanning across different teams helped them build and maintain communication networks and relationships among team members in the organization. One of the participants emphasized on the use of intra-team boundary spanning by building a strong relationship and trust which helped in getting resources including technical support and project funding. This particular boundary spanning theme is exemplified by the quote below:

> *If I needed something that I didn't have, my [team members] were quick to order it or if I needed something they were like, "Oh you can talk to this person and they can tell you more about it. If it's in the plant, they know everything that's in the plant so you can get it from them." Like I was never short of resources. They gave me as much money as I needed. I just had to explain to them why I needed it, what I was going to do with it, and if I needed enough for whatever span of time, I needed it for. So, I always had resources for my project and also resources to talk to as well. [P1]*

There were other participants who went through multiple types of boundary spanning within the organization at the same time. They emphasized on working with different people during the internship experience, which involved their supervisors, and peer and shop floor employees, representing all three different types of boundaries. One of the participants highlighted the use of boundary spanning in multiple levels to solve problems in the workplace. The participant also discussed about understanding people's perspective in workplace at different levels and learning how to deal with them in order to solve problems. The quote below exemplifies the participant's boundary spanning experience:

> *I think that the place where I did most boundary spanning would be in the quality issue as solutions. I would travel with my manager to the manufacturing site and we would have to coordinate with the schedulers to make sure that our product was happening when you wanted it. And then also with the business team telling them we're doing this, or like if we have to do a trial afterwards to make sure that they knew what was going on, how it could affect the business. And then working with different people on the floor, getting their opinions on what we would come in and say, this is a problem that's happening. I think that you'd get a lot of different perspectives in different people when you do that kind of thing*

and you have to make sure that you're considering everyone's opinion fairly and equally. [P3]

3.2 Knowledge/Learning

A prevalent theme across the participants' responses was knowledge and learning, referring to any instance of learning new things or demonstrating the use of previous knowledge in the workplace. Participants emphasized the importance of knowledge and learning in their internship, though the focus of this learning often varied. Perhaps most commonly mentioned was the need to learn specific tasks related to their job. This type of learning was typically grounded in a specific job responsibility, such as technical drawing, as one participant discussed:

> *I remember that the first day I went home and I, like, researched using a laser cutter and, like, the different lenses and all that good stuff. And then I was like, okay, I had to brush up on my CAD designs because I hadn't done that since freshman year. [P1]*

Specific skills like these were typically technical in nature and directly related to the engineering tasks assigned to them. Others mentioned learning to use specific machines, understanding complex engineering processes, or familiarizing themselves with a new software. But participants also discussed the value of learning more broadly about their field or industry. For many, internships became the first time they experienced their major outside the classroom, giving them a first-hand look at the type of work performed in the field. A participant from chemical engineering reflected on her experience:

> *I think that since I was in a CBG company, I was a little less ... you're using separations in this big huge plant, and you're applying that knowledge, but it was a lot of seeing how the manufacturing and the R&D intermingled with each other and how the company worked through a work flow, stuff like that. [P3]*

Using the internship as a chance to gain exposure to the field provided her with the chance to see how manufacturing and research worked hand in hand to produce a product. Leveraging the internship an opportunity to acquaint herself with the field provided her with real-world experience in her major.

For others, the internship was less about learning specific things, and more about learning itself. In fact, a few participants specifically recognized learning to learn as one of the biggest advantages of doing an internship. One student talked about it in terms of making mistakes:

> *I realize like this is your chance to make mistakes. This is your chance to learn. Like they want you to learn on your own. And so you don't have to come in knowing everything because you're supposed to learn it as you're there or else you're not really going to grow if you already know stuff and you're just going through the motions of it. So, it was really exciting not knowing something and then wanting to prove to them and to myself that I can do it. [P1]*

For most participants, their internship was an opportunity to learn and grow their knowledge. This learning came in different forms. For some, it was a chance to learn a specific task relevant to their responsibilities. For others, it was an opportunity to better understand their major and their industry. But for many, it was less about learning specific things, and more about using the internship itself to make mistakes and learn outside the classroom.

3.3 Problems

Not surprisingly, participants discussed the problems they faced while interning. These problems tended to fall into one of two categories: technical and professional. Technical problems were typically encountered in relation to the project the participant was working on, as one participant explained:

> *… So, I came out with the idea of going to...of doing a lot of simulations as close to straight as possible to be able to predict that motion. And that I was able to do. But there is a lot of times where he would give me a lot of guidance but didn't know how to get there. So, it was a little...I learned a lot of problem-solving strategies while working there. [P4]*

Here the participant describes running into a technical problem associated with predicting a behaviour, even describing the process she went through to address the challenge. These technical problems were the most common type of problem mentioned during the interviews, but professional (or non-technical) problems were often encountered in working with others during the internship. These problems were related to finding work, getting help, cooperating with others, and other issues. For example, one participant reflected on seeking help and mismatched expectations:

> *I think my biggest challenge was definitely getting help from the people above me and from the people around me. I know that they have a lot of important work to be doing, but if I get assigned a role, it's obviously important enough for me to get it done. So a lot of times I would have people reschedule on you a lot or if I got into a meeting they'd be like, "Oh, well, I don't really think that's important," or they would kind of try and change my entire scope of what I was doing when I had developed it with my manager. [P3]*

The participant expressed frustration not only with finding help from their co-workers, but also receiving conflicting opinions from those that agreed to help. Generally speaking, problems like these encountered throughout the internship interfered with the participants' work and became challenging both technically and professionally. Nevertheless, they gave participants a chance to improve their problem-solving skills and better understand the types of challenges often encountered in a professional engineering setting.

3.4 Communication/Coordination

A Communication and coordination together formed another important theme that participants mentioned in their interview. Participants frequently emphasized the importance of effective communication in the workplace. Effective communication

included knowing how to interact with different groups of people, including supervisors, clients, and shop floor employees, both in and outside of workplace. Communication also included demonstrating both formal and informal presentations at different organizational levels. In particular, one of the participants discussed on getting compliments from clients and team members after demonstrating effective communication skills through a formal presentation. The accomplishment is exemplified in the quote below:

> *I basically presented my work to the [Client Name] and just the feedback I got afterwards... The first [client] came up, he's like, "Your IQ must be amazing, because you're only a junior at [College Name]." They were coming up and they were like, "You're so young and you're accomplishing all this stuff," and I'm like, "Oh my God." I didn't realize that what I was doing was so impactful for the [Community Name]. That's the proudest moment of my life. I got in my car afterwards and I just smiled, and I went like this on my wheel. I was like, "Yes, like you did it." So, that was definitely my biggest accomplishment [P4]*

Participants also spoke of coordination, specifically coordinating their own schedules. Often faced with multiple responsibilities and looming deadlines, they discussed having to organize their time to accomplish the tasks given to them. One participant reflected on her process:

> *And after our little huddle I would go back to my desk and then I would schedule what I wanted to do for the day. If I wanted to keep going with my shadow board fixtures, I would say well from this time to this time I would do like lines one, two and three and talk to them and try to make their shadow boards. And then from this time to this time I would train the contractor on the kidding initiative that we were doing. And so I'd train her and then I would tell her that these, and I would also make up like a plan for her to guide her with who goals she would have to meet for each week. So like each task that I would give me would take a while, but I made sure to a lot like specific times for that. [P1]*

For many, internships became the first time they were required to structure their day on their own. Whereas some were accustomed to their schedules being organized around classes and extracurriculars while in school, their new role in the workplace emphasized the importance of effective time management. Generally speaking, both communication and coordination became highly important skills for most of the participants in their day-to-day activities.

3.5 Preparation

A During the interview, participants talked about using previous knowledge, activity or experience that helped them prepare to transition as interns. Much of the preparation centered around technical and professional skills developed in college that were successfully transferred to the internship. Participants highlighted the first-year engineering program which taught them both technical skills like programming, and professional skills like teamwork. According to most of the participants, these

skills were both important and necessary when they transitioned as interns and helped them in solving engineering problems in workplace. The quotes below exemplify the preparation of the participants from college:

> *The course really helped your mind evolve to think in an engineering way and just like approach problems as an engineer. If I'm given a problem, I make sure that I understand the problem so that I'm not doing extra work that wasn't needed to begin with. I didn't know that I was actually learning a lot in foundations even though like you know they teach you like all of the different types of engineering you're learning. Like I was like okay I'm using [Software], but I never saw [Software] again personally for me in my other classes. So just knowing that, oh I actually do use this stuff was like, oh I'm learning, I'm actually learning [P1]*
>
> *I think that with the whole First-Year Engineering Program, you get a lot of team activities that you can do. And then, within chemical engineering, it is super technical, but they do throw in those classes and it's so hard that you really have to work with people in order to accomplish all of it. So, I think that I really did have that background in order to work on this. [P3]*

3.6 Value of Internships

A In reflecting on their experiences, all participants shared their perceptions of the value internships provide to engineering students. Much of the value centered around learning new skills, both technical and professional. Some participants found these skills helpful as they moved back into the classroom after their internship, providing context for the material and even bolstering their presentation and other professional skills. Several participants appreciated being able to see first-hand what can be done with the degree they are pursuing, using the internship as a gauge for whether they were interested in the type of work they experienced. Other participants mentioned the value of making connections during their work experience, indicating their plans to leverage those connections as they move into the job market. One participant summarized the value of an internship broadly:

> *I think experiential learning in itself is very, very valuable. I would never have known what I like and what I don't like. I feel like internships really enable you to understand a holistic perspective, whether that's within your field, you know you gain different skills, you gain those technical and social and personable skills. I think it also affects our professional competencies, like global perspectives, and communication, leadership and I think that's what really makes students stand out, if they have more experiential learning opportunities. That is like it just enhances your overall like college experience, in my opinion. I really, really value experiential learning and so I feel like internships and co-ops overall are very beneficial. [P2]*

Useful for a variety of reasons, internships were discussed in a positive light amongst almost all participants, cementing their role as a valuable experience outside the engineering curriculum.

4 SUMMARY AND ACKNOWLEDGMENTS

This work used a qualitative approach to understand engineering students' experiences with internships. In terms of limitations, the study had difficulty in recruiting participants for the interview due to unavailability and time constraint of many participants. However, the researchers are actively recruiting participants with similar experiences to broaden the research scope for future studies in this context. The results of the analysis led to the identification of six important themes. Each theme highlights an important aspect of internship, speaking to the variety of benefits these experiences provide. Among these was knowledge and learning. Throughout their internships, participants gained a diverse set of new knowledge, using the experience as an opportunity to learn about engineering processes, as well as their potential role within the engineering field, these results align with previous work on internships we have conducted in other contexts [17]. Learning also included professional skills like teamwork and communication which were necessary to accomplish project goals, this is consistent with previous findings of our work in teamwork and professional skills [18]. However, this did not take place without problems, as most participants mentioned both technical and professional challenges that occurred throughout their internships. Despite these problems, most participants described internships as highly valuable, allowing them to gain new skills, make connections, and experience the engineering field firsthand. The value of academic preparation both in terms of technical skills and professional skills were also highlighted by the participants, this reinforces the expectations posed by the ABET criteria [10]. With positive feedback from students' internship experience, we believe that internships add value to the student's learning in engineering and academic leaders need to encourage students in participating in internships or even find better ways to integrate internship experiences within the academic curriculum. The successful transfer of these skills helped them solve engineering problems and collaborate with people at different levels in the workplace. Participants have acknowledged the term 'boundary spanning' and described scenarios involving different types of boundary spanning which aligns with the theory we used for the study [9]. Our paper gives a preliminary understanding of internship experiences of engineering students and our current findings demonstrate that more research is required to understand students' experiences during their time outside of school in the complex engineering world.

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ENHANCING SERVICE MATHEMATICS TEACHING THROUGH STRATEGIC ALIGNMENT

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Conference Key Areas: *Mathematics in the Engineering Curriculum; Linking different disciplines both inside and outside engineering*
Keywords: *Service mathematics; Alignment; Project-based learning; Twente Educational Model*

ABSTRACT

Service mathematics teaching, such as calculus for engineering, needs to be aligned with the requirements of the departments it is servicing. Service mathematics courses can be subject to criticism if they are perceived to suffer from poor alignment. Designing such courses requires communication between the mathematics department and the engineering departments and this communication should remain ongoing as the needs of the students change or as teachers with different experience and mathematical preferences change.

In the Twente Educational Model the bachelor's degree is divided into twelve modules, each lasting one quarter of the academic year. In each module the students work in groups on projects and the project is supported by disciplinary units or skills development. Module design differs across and within departments, but the basic structure of supported project-based learning is ever present. The quarterly project reports provide insight into the work the students draw on to understand and complete their projects and offer an opportunity to determine whether the students have the mathematics knowledge and skills needed for their project assignments.

To investigate existing alignment and to seek ways of improving alignment we embarked on a project of distilling mathematics content from reports. While alignment was good in general certain points for improvement were apparent, both in the realm of content (for example important differential equations) and in key skills (for example interpretation of graphs). In this presentation I shall provide a brief synopsis of findings as well as present and reflect on the methodology of the project.

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1 INTRODUCTION

1.1 Service mathematics

Much of the mathematics taught at universities is taught to non-mathematics majors, such as students of engineering, economics and physical science. These co-called "service" courses are often taught by people who do not share the same disciplinary speciality as the students being taught. It is important that the mathematics included in such a course meet the needs, as far as is possible, of the discipline and the other courses the students will take and for which they will require mathematical knowledge and skill [1].

The need for alignment between the mathematics taught and the mathematics needed can be partially approached as a checklist of topics, for instance do we include complex numbers, multivariable calculus, compound interest and annuities and so forth, but the need for alignment is greater than a list of syllabus topics. Different disciplines have different discourses, different uses of (technical) language and different modes of engaging with the world. A mathematics course well aligned with the discipline of engineering contributes to development of an engineering identity [2,3].

Studies considering alignment between service mathematics courses and the disciplines they serve have been fruitfully carried out via interviews with and observations of lecturers [4] or students [5] or analysis of assessment for evidence of "transfer" [6]. The project-based learning practised at the University of Twente allows for an opportunity to compile a set of mathematical topics, skills and general processes not from the top down, but from the project reports, thereby by definition embedded in disciplinary context. Anecdotal evidence suggests that while alignment between the mathematics courses taught by the author and the programmes in which they are located is acceptable it could be improved. The study of which this paper forms part aims to improve alignment by utilising project reports as contextualised indicators of disciplinary mathematics requirements. The qualitiative method of thematic analysis was used to identify themes to inform the research questions.

1.2 Twente Educational Model

A bachelor's degree at the University of Twente is structured as a series of twelve thematic modules each lasting one quarter of an academic year. Each module consists of a cluster of courses or units as well as a project which the students complete in groups. An example is module 1 of Advanced Technology, Mechanics, where courses (or units) on mathematics, mechanics, laboratory practice and academic skills support a project modelling a dynamical system [7].

The degree to which the courses integrate with one another and with the project differs across modules. While the "ideal" of the Twente Educational Model (TEM) is that the courses in a module all support the project in some way in order to encourage an intrinsic motivation to learn [8] this is not always possible. Mathematics in particular can suffer from lack of alignment with any one particular module given that there is a certain body of calculus and linear algebra that is required to be taught across the first year and the technical areas in which it will be used may only be encountered by the students in a later module or year of study.

At the end of each module each group of students has to submit a report on the module's project. The reports provide a valuable opportunity to see, in situ, what mathematical skills, concepts, techniques and processes (in this paper referred to collectively as "topics") were employed by the students and hence to determine how well the mathematics courses are aligned with student and disciplinary need and whether the alignment could be improved by either minor or major changes. The method of thematic analysis was used to analyse and organise the data.

1.3 Research questions

- What mathematics skills, concepts, processes or techniques are observed in the project reports?
- To what extent are the mathematics courses aligned with the projects or do they support the projects?
- In what ways could the mathematics courses adapt or change to better align with or support the projects?

Finally, not a research question but a reflection,

- How effective was the method of thematic analysis in suggesting ways of enhancing alignment?

2 METHODOLOGY

2.1 Thematic analysis

Thematic analysis is a qualitative method for identifying, analysing and reporting themes in data [9]. One begins with a data corpus, in this case the collection of all project reports, and chooses a data set within that corpus for analysis, in this case the data set is instances of use of procedural mathematics. Braun and Clarke [9] suggest a set of six phases for thorough thematic analysis. In this study the analysis was framed as "three passes through the data" where the first pass, reading the reports and making a concise list (per group) of anything of mathematical interest can be aligned with Braun and Clarke's first two phases of familiarising oneself with the data and generating codes. The second pass, that of organising the data more meaningfully in a summary (per module) is also aligned with phase 2. The third pass, to identify and name themes, align with phases 3-5. Braun and Clarke's phase 6 is to produce a report of which this paper represents a part.

In the context of mathematics as a part of engineering studies, Faulkner, Earl and Herman [10] use thematic analysis to better understand how engineering faculty view mathematical maturity, that is as skill at modelling and recognising the role of mathematics in underatanding the real world. Similarly Engelbrecht, Bergsten and Kågesten [11] employ thematic analysis of interviews with practising engineers to conclude that while both procedural fluency and conceptual understanding are valued in the workplace mathematics taught to engineering students should be more conceptually than procedurally oriented.

2.2 Context

The two programmes included in this study were Advanced Technology (AT) and Electrical Engineering (EE), specifically the four first-year modules. At the end of each module the students submit reports on projects on which they work in groups. As a member of the teaching team I am permitted access to those reports although I am not directly involved in the projects. No examples of student work or identifying information is included in this study.

2.3 Data collection and analysis

First pass: To read project reports and generate codes. The project reports were read and mathematical skills, processes, concepts and techniques (collectively "topics") that were observable in the students' work were recorded resulting in a short list per group. A procedural view of mathematics was explicitly taken here. For the purposes of this analysis mathematics was considered as a toolbox of procedures and techniques rather than mathematics as problem solving, or "thinking mathematically" [12,13]. Undoubtedly viewing the project reports through a different lens would reveal different and rich data, but the task at hand in the analysis discussed here was to determine indications of concrete curriculum content.

Second pass: To determine the most prevalent mathematical topics. The first pass produced topics clustered by group. In the second pass those topics were considered collectively and a summary was produced making note of the most prevalent topics in each module. Also in this second pass the content of the concurrent mathematics course was considered and whether the course in any way supported the project.

Third pass: To look at the entire data set and identify themes including but not limited to: topics that could be included in the mathematics courses to better support the projects, and topics that are already included that are clearly supporting the project.

3 RESULTS

3.1 Three passes through the data

The project reports from two programmes across four modules have been analysed. Table 1 lists the academic year, module, programme and broad project context.

Table 1. Project contexts by programme and module

Academic Year	Module	Programme	Project topic
2018-2019	4	AT	Accelerometer
2018-2019	4	EE	Antenna
2019-2020	1	AT	Dynamical system
2019-2020	1	EE	Sensor package
2019-2020	2	AT	Cooling system
2019-2020	2	EE	Solar inverter
2019-2020	3	AT	Materials for application
2019-2020	3	EE	Audio amplifier

AT: Advanced Technology
EE: Electrical Engineering

The first pass through the data revealed immediately that keeping a detailed and exhaustive count of mathematics topics would be impossible. The same engineering subject matter written about by two groups could and did include very different representations of mathematical processes. Sometimes a topic was so prominent that everyone included it (a system of differential equations, for instance) but on the whole a general sense of what the students found useful was all that could be recorded. A surprising finding of this first pass through the data was not content related but more stylistic. For instance a wide variety of Greek letters was used by both programmes in multiple modules, suggesting that the mathematics courses could display a similar prominence and thereby at least display a symbolic similarity with the technical programmes. Group numbers were recorded, but no names, each accompanied by a list of observed mathematical skills or techniques. An example:

Group 1

- Step function
- 2nd order DE
- Error estimates
- Estimation of quantities
- Manipulating symbolic expressions
- Differentials
- Damping
- Graphs

For the second pass through the data the points noted in the first pass were clustered into those that were present in all or many of the reports and those that appeared only once or twice and a module summary was drawn up. Thereafter the

content of the concurrent mathematics course was considered and links were sought between the mathematics course and the summary, laying the groundwork for identifying themes. Alignment was classified as None, Weak, Good or Significant. Table 2 indicates that alignment was Significant in one case (AT module 1), Good in one case (EE module 1), Weak in two cases (AT and EE module 2) and None in four cases (AT and EE modules 3 and 4).

Table 2: Alignment of mathematics course with module project

Year	Module	Programme	Alignment
2018-2019	4	AT	None. The mathematics course is entirely linear algebra which plays no role in the project. Instead the project primarily uses differential equations.
2018-2019	4	EE	None. The mathematics course is entirely linear algebra which plays no role in the project. Instead the project relies heavily on vector calculus.
2019-2020	1	AT	Significant. A core topic of the mathematics course is differential equations which are used extensively in the project. Another core topic is vectors which are also important in the project.
2019-2020	1	EE	Good. A core topic of the mathematics course is vectors which are important in the project. Several project reports include limits at infinity, also a topic covered in the mathematics course.
2019-2020	2	AT	Weak. The project needed very little post-secondary school mathematics. An exception is integration in the form of single variable integration not requiring any special techniques.
2019-2020	2	EE	Weak. The project needed very little post-secondary school mathematics. An exception is partial differentiation which played a minor role in the project.
2019-2020	3	AT	None. The project needed very little post-secondary school mathematics. A possible exception is determining best-fit curves to data points.
2019-2020	3	EE	None. The project needed very little post-secondary school mathematics.

AT: Advanced Technology

EE: Electrical Engineering

The TEM ideal of the courses or units gathered together in a module all supporting the central project of that module is only apparent in module 1 for both AT and EE. This is not a problem, however, for two main reasons: First, the projects in the other modules are not using or needing mathematics which is not available to the students, that is there are no key topics that have been "omitted" to the impoverishment of the students' experience in the module. Secondly, the mathematics courses, in particular the three calculus courses, form a cohesive body of work that is drawn on generally. A good example is the third calculus course (included in module 3) which covers vector calculus which then forms a powerful tool for use in the EE module 4 project. If the four EE first-year modules form a "meta-module" [7], as it were, then the TEM structure is indeed apparent.

The third pass through the data was focused on identifying themes, or categories. The categories recognized as emerging from the data were: (1) mathematical topics or techniques that can relatively easily be changed or included in the syllabus, (2) mathematical topics or techniques it would be valuable to include, (3) mathematical topics or techniques that are already in the syllabus and were clearly useful in the projects, and (4) ideas related to style or appearance. This method of identifying themes [9] call "inductive" or "bottom up".

3.2 Categories

1. Topics for change

The "topics for change" are a collection of mathematical topics that were evident in the data but not present (or not prominently present) in the mathematics courses, yet could be included without much difficulty.They are an increased focus on graphing, differentials and error propagation, and specific examples of certain mathematical concepts, such as damping, Hooke's Law and the binomial theorem.

Graphs: Something that leaps out of the project reports is the heavy reliance on graphing. The students graph their experimental outputs both as continuous curves and as discrete data. They present the ideal curves that the models predict and compare their data graphs to those of the model. In some cases they determine best-fit straight lines (or other curves) to scattered data points and in all cases they need to interpret all the relevant graphs. Sinusoidal curves and the arctan function were particularly applicable functions and horizontal asymptotes made several appearances.

Differentials and error propagation. Differentials made an appearance across several modules as do the concepts of error and error propagation. The first calculus course, in module 1, begins with differential equations since the students need understanding of what differential equations are and some skill in solving them early

on in the module, both AT and EE. Therafter the course deals with complex numbers (needed for second order differential equations) and vectors, another important topic. The course then closes with a cluster of topics generally related to differentiation, such as limits, continuity, tangent lines and extreme values. Differentials and error propagation would be a good fit at the end of the course.

Damping and Hooke's Law. Second order differential equations are a core topic in the first calculus course, however in the current curriculum damping is not covered. Simple harmonic motion with damping could be easily included in the syllabus, similarly Hooke's Law which is ubiquitous in the project reports could be included as a contextual example without any difficulty.

Binomial theorem. In the second calculus course we cover sequences and series in great detail. The students often struggle to see the relevance to any of their other work, such as calculus or their technical subjects. The binomial theorem, encountered a few times in the project reports, would be a relevant example to choose, along with the binomial series.

2. Valuable topics to include
The "valuable topics to include" category is a collection of topics that, if included in the mathematics courses, would improve alignment, but are not easily incorporated in the courses as they currently exist. Further thought is necessary to consider how to include them. There were three topics fitting this description. The first was the geometry of parabolas, specifically the role of the focal point. The second was the catenary, a curve with important real world applications and also an opportunity to refer to hyperbolic trigonometric functions. Finally there were the trio of square wave, triangular wave and sawtooth functions, all of great importance in EE module 2.

3. Relevant syllabus topics
The mathematical skills and techniques already included in the existing mathematics courses and obviously present in the project reports included single variable integration, partial derivatives, vector calculus and 1st and 2nd order differential equations. Also present were vectors (with the same notation we use in mathematics, which is interesting given the lack of global convention of vector notation [14]), complex numbers, limits at infinity, sigma notation and polar, spherical and cylindrical coordinates. As a teacher of engineers without herself having an engineering background, it is extremely helpful to see where the mathematics I teach is used.

4. Style elements
Symbolic usage in the reports revealed two common characteristics generally not shared with mathematics, that of using many Greek letters and manipulating large symbolic expressions with many constants or variables. The symbols used in mathematics tend to fall within a small set of Roman and Greek letters. To a student

new to university and unfamiliar with seeing these symbols it can demystify them if they are encountered more ubiquitously than only in certain courses. The dot notation for time derivatives is widely used in the AT and EE project reports. This dot notation is not currently used in the mathematics courses but it is trivial to introduce and include.

The research questions were

- What mathematics skills, concepts, processes or techniques are observed in the project reports?
- To what extent are the mathematics courses aligned with the projects or do they support the projects?
- In what ways could the mathematics courses adapt or change to better align with or support the projects?

The first and second passes through the data answered the first question, the second pass answered the second question, and the third pass answered the third. The result is a strategically chosen collection of changes to the existing mathematics courses that will improve alignment. Continued communication within the module teaching teams remains important for many reasons, one of them being possible changes to the module project resulting in different needs for the mathematics courses.

3.3 Reflection on the methodology

It is important for a service mathematics course to be aligned with the needs of the discipline it is serving and the teaching and learning programme in which it is situated (such as these TEM modules) [15]. Typically to achieve that alignment either the mathematics is taught by people already embedded in the discipline or the two parties communicate over what is needed, perhaps using checklists of topics. The methodology of thematic analysis employed in this project is particularly suited to a pedagogy based on project-based learning, as TEM is. It takes a very particular and very practical view of the alignment of the mathematics course to the students' learning needs. A limitation of the method of using project reports is the significant differences between what different groups chose to include and hence the likelihood of something important not being apparent. As a mathematics lecturer without an engineering background I found this study extremely informative and educational. I have a much clearer idea of what the projects entail, what the students need and how mathematics can help. The next challenge will be to incorporate the changes discussed above.

4 SUMMARY AND ACKNOWLEDGMENTS

The study reported in this paper will be carried forward by communicating the findings of the thematic analysis with colleagues in the two disciplinary programmes in order to spur conversations of mutual benefit. Furthermore two initiatives are under development with the two disciplinary programmes: in advanced technology

workshops are being planned linking calculus and mechanics, and in electrical engineering a project involving the creation of a suite of contextualised mathematics exercises is being planned.

Finally, in summary, the methodology of using students' written project reports as an indication of mathematics of importance in disciplinary context was successful and highly informative. The results of analysis will certainly bring about change in the mathematics courses to better align them with the needs of the projects, in line with the vision of the Twente Educational Model [8].

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EXPLORING THE IMPACT OF BREXIT ON UK'S ENGINEERING EDUCATION SECTOR FROM THE PERSPECTIVE OF EUROPEAN STUDENTS AND STAFF

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ABSTRACT

The United Kingdom has a tradition of excellence in higher education and is recognised as an important player in engineering education and research globally. With 20% of the engineering academic staff and 12% of the student body being European (based on official data related to 2017/2018), much has been anticipated about the likely consequences of Brexit, including the disruption of research collaborations and mobility of staff and students.

Understanding the post-Brexit context is important for British higher education institutions, but Brexit also has implications for individuals' home countries, like Portugal, that have a history of sending graduates to the UK. The study reported here is part of a larger project funded by the Royal Academy of Engineering to explore, from the perspective of European students and academic staff, the impact of Brexit on the UK's engineering education sector. In this paper, we interrogate the perspectives of three Portuguese citizens engaged in engineering education in the UK – two women including one undergraduate student and one postgraduate student, and one man who serves as a lecturer. The transcripts of semi-structured Interviews were coded thematically to identify: (1) participants' motivations to come to study or work in engineering in the UK, (2) their experiences and future career plans, and (3) whether all of these were impacted by Brexit.The outcomes of the project will be relevant to predicting the future of engineering education, and estimating the impact Brexit wil have on mobility and research collaborations between the UK and European higher education institutions.

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1 INTRODUCTION

The UK higher education attracts a far higher number of international academics from all over the world, who teach and do research, than any other country in Europe, being only surpassed by Switzerland [1]. Moreover, because engineering itself is considered a global field, this sub-field of higher education also relies on international mobility more than most academic disciplines in the UK

The impact of the *United Kingdom European Union membership referendum of June 2016*, commonly referenced as the *Brexit referendum*, is still unfolding and under continuing analysis. However, it is widely anticipated that it will disrupt European student and staff mobility and may have negative repercussions for education, research and innovation [2]

Data analysis conducted by the UK's Higher Education Statistics Agency (HESA) regarding European students and staff revealed an increase of 6.5% in the number of undergraduate engineering students from EU countries in the academic year immediately following the referendum (2016/17) [3]. By this time, across engineering faculties in UK, European academic staff (teaching, research) comprised 17.4%. Comparing this 2016/17 figure with 2015/16 reveals a 6.5% increase of European academic staff overall. Looking only at research staff in 2016/17, one in four academic researchers (26.4%) was European; this reflects a 3.1% increase from the previous year. These numbers suggest that although UK universities are still attractive destinations for European academics, staff on 'research-only' contracts may not be as readily enticed to move to the UK after the Brexit as other types of academics. This could be due to instability of funding available from Europe as well as UK sources to support work of foreign researchers workgin in the country. As for students, speculative interpretation of the above data suggests that EU students may have been taking the opportunity to study engineering in the UK as a 'last chance' before fees, funding and visa requirements change. However, more detailed data are needed to assess if these speculative hypotheses are accurate and also to understand the impact of the Brexit decision on European students and staff members who are currently studying or working in the UK's engineering higher education institutions.

Prior to this study, no data on experiences and perceptions had been collected from European engineering students and academic staff regarding Brexit, making it difficult to anticipate the impact the UK's departure from the European Union might have on the engineering education sector. Understanding concerns and expectations held by European students and academic staff is essential to achieving evidence-based decisions to effectively support the recruitment and retention of European talent into UK engineering education. The research project reported here has collected and analysed data regarding the impact leaving the European Unions may have on mobility, funding, skills development, future study and career prospects of Europeans involved in engineering education in the UK.

1.1 Project "Brexit impact on UK's engineering education sector"

In April 2019, the Royal Academy of Engineering funded the project "Brexit impact on UK's engineering education sector: Exploring EU students and staff experiences", a joint collaboration between the UCL Centre for Engineering Education (CEE) and the Engineering Professors' Council (EPC) in the UK. This project aimed to contribute with new and critical understanding of motivations and limitations related to studying and working in the UK. Issues such as mobility, funding, skills development, future study and career prospects have been included. The research team is collecting data from students at undergraduate and postgraduate levels of study, and from academic staff on both research-only, teaching-only, and research-and-teaching contracts. The outcomes of this project will be useful for the engineering education sector in the UK by providing insights for those involved with recruitment and retention of students and academic staff. Ultimately, the project will also provide greater understanding of the landscape of international and pan-European collaboration across Engineering Education.

Although data on the post-Brexit context are important from the point of view of actors and stakeholders in British universities, the Brexit phenomenon also has implications for countries that have a history of sending graduates to the UK. In recent years Portugal has been one of these countries. In the wake of the economic crisis in 2008, there was a widely reported 'brain drain' wherein graduates left Portugal *en route* to the UK or other Northern European countries [4,5]. This has been a source of concern across Portugal. An additional factor at play in the Portuguese context is that while there has been an enormous expansion of access to higher education since the country's political revolution (establishing, in the 1970s, democratic independence from the former dictatorship) and there have been more women than men entering its higher education institutions for the last 30 years, the number of young women enrolling on engineering programs has been relatively low at around 26% [6,7].

Keeping these factors in mind, this paper focuses on Brexit-related perspectives contributed by three Portuguese citizens currently engaged in the UK Engineering Higher Education sector. These Portuguese participants in the larger research study provide valuable insight that warrant their own dedicated reporting. SEFI is an ideal venue to share such findings as understanding Portuguese involvement in and contributions to different education systems outside can benefit the European engineering education community.

This small qualitative study aims to address the research question: what factors do Portuguese citizens engaged in the UK Engineering Higher Education sector perceive as important in planning their future?

2 METHODOLOGY

2.1 Research Design

The overall project has adopted an exploratory mixed methods design involving a qualitative phase (interview, reported in this paper) followed by a quantitative phase

(online survey, currently ongoing). In the qualitative phase, a diverse sample of European students and academic staff members currently studying or working in UK Engineering higher education institutions were interviewed to explore their experiences, concerns and future expectations following the Brexit referendum. Key issues identified in this phase are now being explored via a quantitative phase, wherein a larger sample of European students and academic staff across the UK is being engaged in an online survey.

In the interviews, students and staff were asked about: factors they considered when choosing to study/work in the UK, career prospects they expected to have, and experiences and skills they were expecting to achieve; their experience in the UK overall, and what impacts they had felt as a result of Brexit; and what their career plans entail, and their prefrences regarding leaving or remaining the UK.

Answers provided by each interviewee were followed-up with probing questions to yield further insight. The interviewer (this paper's lead author) raised the topics of mobility, funding (e.g., tuition fees and research grants), international research collaborations, career development, institutional support and legal advice.

At the time of writing this conference paper, the qualitative phase of the larger study had been completed, and the quantitative phase was under development.

2.2 Procedure

After approval was granted from the UCL Ethics Committee, participation calls and participation information sheets were circulated via EPC newsletters and relevant social media (Twitter and LinkedIn). All interviews were conducted before the UK General Election occurred on the 12th of December 2019, and well before the COVID crisis, both of which would have influenced the narratives provided. Online interviews were conducted in English and recorded for professional transcription.

This paper presents thematic analyses of a subset of interviews with three Portuguese participants, since only Portuguese citizens were represented across three different groups of interviewees: undergraduate students, PhD students, and academics. Thematic analysis [8] of the data was chosen as a methodological approach as there was an interest in finding themes in order to answer the research questions. This type of analysis was also chosen by other researchers who conducted a small-scale qualitative study exploring the impact of Brexit on the career aspirations of final year British students [9].

The open-ended approach of the interviews was suitable for this methodology as thematic analysis "is not wedded to any pre-existing theoretical framework" [10, p. 81].

2.3 Participants

A total of 24 participants (15 academic staff and 9 students) were interviewed between October and early December. This paper focuses on interviews with three participants, chosen to provide an understanding of the Portuguese context. These participants are: Sofia, an undergraduate student; Paula, a recent PhD recipient, now working as a post-doc; and Luís, a lecturer who is currently doing a PhD. All

names are fictitious. Their academic profiles, engineering sub-fields, places of work/study and year of having moved to the UK are shown in Table 1.

Table 1. Subset of Portuguese participants

Participant	Academic Profile	Year moving to the UK
Sofia, Undergraduate (England)	3rd year undergraduate student in Biomedical Engineering	2017, after Brexit referendum
Paula, Postgraduate (Northern Ireland)	Postgraduate student In Environmental Engineering recently appointed as Post-Doc	2016, before Brexit referendum
Luís, Lecturer (England)	Lecturer in Mechanical Engineering currently doing a PhD	2014, before Brexit referendum

3 FINDINGS

3.1 Factors and expectations when coming to study or work in the UK

Sofia had never considered studying abroad until she heard, from a company visiting her secondary school, that the learning style in UK universities was more practical than in Portuguese universities.

> *I was told that in England it was more practical. It was not so theoretical as in Portugal. I wanted to take the risk and see how it was and actually, it has advantages for me to go out of the country*

She was interested in gaining work experience after graduation, and saw more opportunities to do that in the UK.

> *Also, the recognition after [graduation] (…) they have a lot of employability. I was planning on maybe staying here [in the UK] for one year or something, just to earn money because it's really good here, compared to Portugal, they earn more. Of course, it's a different lifestyle, but it's good for opening my career (…). And they have a lot of placements, that's really good and even in the master's, they have partnerships with another university, which is also really good.*

Sofia mentioned that having a degree from the UK on her CV was something that would have a higher value than a degree from Portugal.

> *For the CV it's really good (…) for them to see my CV, and that I was studying in England, that I had some internships (…). It's better compared to taking a graduation in Portugal.*

This perceived value of a UK degree was also mentioned by the postgraduate student. Paula, having studied in Portugal for both her bachelor's and master's degrees, envisioned herself pursuing a PhD abroad. She mentioned the value of a UK degree, and the opportunity be fully funded for study as the main drivers for choosing the UK.

> *Well, considering I did the bachelor's and the master's in Portugal, I wanted to have a PhD somewhere outside of Portugal. At the time I applied to a lot of universities, even Australia for example, and the US. But I always wanted, deep down, to come to the UK because (…) it looks well on the CV to do a PhD in the UK. (…) I don't really understand, but apparently doing a PhD in the UK was*

always very highly esteemed, so I wanted to come here. (…) I tried for a year and a half, almost two years before I successfully got this PhD because I wanted a fully funded PhD. There was no way I could live abroad just by myself, so I needed a fully funded. At least at the time, there were a lot more opportunities in the UK than in other countries (…).

Luís completed his bachelor's degree in Portugal and tried to become involved in projects in his area of interest. However, as none of these projects came to fruition, he decided to explore other opportunities and found the possibility to pursue a master's in the UK.

I've always had an interest, growing up, in this subject area. I felt like I needed more specialized knowledge on the field to have an easier access into the industry (…) [coming to the UK] was solely based on the availability of the subject area. I came to do Motorsport Engineering. It's a degree that not all countries have. Certainly, my home country doesn't have that degree, there's no market for it.

Following the completion of his postgraduate degree, he was offered a PhD scholarship, and also a teaching position at the same institution, and he decided to accept.

I was offered a scholarship to do the PhD. It was never the plan initially to stay for research or anything. Staying for work was being considered, but then, yes, the scholarship – I thought "this is the opportunity to attempt taking a PhD. It will be now. Later would be much harder". Teaching commitments started soon after as well. It was just having the opportunity for doing that, if that makes sense.

3.2 Experiences in the UK and impact of Brexit

The three interviewees shared positive experiences in the UK, at both professional and personal levels.

Sofia was enthusiastic about her learning experiences at the university, and stated that lecturers were supportive and approachable, and that being part of a small class was beneficial.

I realized it was even better than what I'd thought. It's very practical. Professors – I have a very good connection with them, and we are a small class. We are only 13, so it's really good. We are very close with the professors. It is amazing!

Sofia also mentioned that, compared to Portugal, the UK's culture was more accepting of people's individualities and that this was something that she cherished. She also valued the opportunity to connect with colleagues from different cultural backgrounds. Regarding Brexit, Sofia was initially worried. She was being informed by the Portuguese company and was going to apply for UK pre-settlement status.

Paula was also very enthusiastic about both her professional and personal experiences in the UK, specifically in Northern Ireland. She enjoyed her PhD journey, and valued the skills and knowledge she acquired as also being part of a welcoming and supportive research group.

I learned how to build actual reactors to make the experiment, which was super interesting because I had never built one from scratch. (…) I did learn a lot, especially in areas that I didn't have that much knowledge, so it was quite

interesting (…) I really enjoy, and I absolutely love, the group I work with. How approachable they are; and the exchange of knowledge is really nice as well. I absolutely love it, otherwise I wouldn't have stayed anyway [chuckles]. But I absolutely love it. I really like it here.

She was also very pleased with her lifestyle in Northern Ireland and said that the resemblances between Northern Irish and Portuguese cultures made her feel at home. At the time of the interview, Paula was still sceptical about outcomes of the referendum. She was hoping that the UK would not leave the European Union. She based this hope on the constant postponing of Brexit deadlines by the UK government. At a personal level, she hadn't noticed any differences since the referendum, but agreed that the there was tension every time a deadline approached. This tension was especially high prior to the initial leave date, scheduled for the 31st October 2019, when she decided to finally apply for pre-settlement status. In terms of the impact on universities, she was particularly worried about getting access to research funds in the future, because she could see herself pursuing an academic career in the UK.

They [university] were scared (…) because funds were going to be cut, because most of the things come from the European Union.

Luís was pleased with having access to opportunities that he hasn't even considered before coming to the UK.

I think it's been good. Certainly, I have access to a lot of opportunities which I'm sure wouldn't have happened. But at the same time, they weren't planned [chuckles]. It's been interesting because none of these… ending up teaching wasn't the plan coming here. It's been interesting and rewarding, for the most part.

He was worried about the negative impact of Brexit on feeling welcome, free movement and overall welfare. He also stated that Brexit would have a negative impact on various industry sectors at a national level, but wouldn't affect his collaborations with local industries.

The commercial vehicle, the automotive side, definitely, there's potential for disruption of the industry in the UK. The UK has, I think, engine manufacturers. I'm sure there will be disruptions to some extent, at least until they figure something out to get goods to the other side in a way that complies with legalities, administration issues. The other one would be [related to] the workforce itself. (…) A lot of our industry is close by. Even though a lot of the workforce for that industry is international, but they're pretty close by. The communication hasn't deteriorated in any way. The industry itself will have their own challenges. As far as our relationship, that I'm aware of, it hasn't changed.

3.3 Future plans, and intention to remain in the UK

Sofia was planning to apply for a master's and, possibly, a PhD position in a UK university. Long-term, work wise, she was considering moving to a different country.

I was not very mature in that time [chuckles] [when applying for an undergraduate degree]. Now I realized that for my master's I want a better thing (…) in that time, I was thinking on the recognition and rankings, and where the students go (…). I

didn't pay much attention because I was so excited to come to England. But now I'm applying for master's for next year. I'm starting now doing applications for [a university in England], and maybe [a university in Scotland] because it's for computer science, and they are both good. (…) if I get into the [university in England's] master's, maybe then I can go for a PhD (…). Then after the PhD, which is a long time from now, I'm thinking on maybe going for a year, or two maybe, working in England, or maybe another country

When asked about the hypothetical scenario of not being able to apply for a master's or PhD position in the UK, Sofia was not sure where to go. However, she was not considering going back to Portugal.

Following the completion of her PhD, Paula got a short-term contract in her university while she waited for her viva (thesis defence). She wanted to stay in Northern Ireland.

Like I said, I really like the group I'm in, and I really like Northern Ireland, so I didn't really want to leave. Then I got extensions and now I have an extension until [a specific date]. There was a time that I wasn't sure if I was going to get an extension or not, and so I was applying to other places.

She also considered enrolling in courses on teaching in higher education, so she could develop a new set of skills to work in academia in Northern Ireland.

I don't know what's going to happen in a year. Well, I think if I can, I'd rather stay but I might think about doing one of those courses, like the courses for teaching in higher education. Maybe start thinking about applying to grants, but then again it will depend if Brexit goes forward or not. Maybe go do some teaching as well. I would like to stay here.

Although she would prefer to stay, Paula was ready to explore other opportunities for postdoc positions outside the UK.

As a lecturer, Luís had already considered exploring job opportunities outside of the UK, particularly in industry.

Definitely sometimes, there are thoughts of exploring positions in other countries, more in the industry than academia (…). Yes, yes, I think [Brexit] definitely has an impact. The question between academia and industry was always there. But now, it's more academia here versus industry, which I could access at somewhere else. Because engineering skills are quite easily transported across borders. They don't depend so much on the local language to a certain extent. They are easily integrated.

His decision to remain in the UK, on the other hand, would be influenced by non-professional impacts of Brexit, such as freedom of movement and quality of life.

For me to continue to think of the UK as attractive as it was before, if we could keep people moving backwards and forwards without any more hassle than it already has, and if life as a whole doesn't deteriorate – ideally it would improve – but if it doesn't get worse than what it is, then yes, I'll be happy to continue here. Professionally, I'm in a good place. (…) So, professionally, I'm not too concerned. It's more to do with the quality of life and enjoying the place.

4 DISCUSSION

Based on having such a small sample size, little of what the participants said can be assumed true for a larger group, yet some of the patterns were very strong across these three Portuguese participants, and resonate with the larger sample of participants. For these three participants, the UK was perceived as offering top-notch education that would be well-received in Portugal and recognized worldwide. All participants described having good experiences in the UK, both personally and professionally. All described supportive learning environments and enjoyable teaching and working styles. They had all felt welcome and enjoyed interactions with peers and citizens but now fear things may change after Brexit. Nevertheless, all three of these participants would like to remain in the UK longer.

They all showed a high level of adaptability in dealing with the many unknowns and uncertainties created by Brexit. They all described upward career mobility following their initial studies in the UK and a desire to learn more and to develop themselves farther in the future. They would all be happy to continue to live and work in the UK, as long as further education and job opportunities remain available, as long as quality of life persists, and as long as they feel welcome.

At the point of the interviews, all conducted before the UK general election (12 December 2019), and the official withdrawal of the UK from the European Union (31 January 2020), these three participants were positive about their experiences in the UK, and the engineering higher education system they found in the country. They remained happy with their choice to come to the UK. However, they realised there might be a need to leave, and they might have to take additional actions to be granted rights to stay and work in the UK.

This paper presents an overview of the initial findings of interviews conducted with European engineering students and staff studying and working in the UK, after the UK's decisions to leave the European Union. The interviews conducted with three Portuguese participants provide a snapshot of what was discussed with the larger, more diverse group of participants. As noted above, the results of these three specific interviews may not be immediately transferrable to a larger population; however, comparing these data with the other interviews and with the quantitative survey data that is soon to be collected, will support wider transferability of the findings.

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WHAT DO OUR STUDENTS KNOW ABOUT THE FUTURE CHALLENGES OF SUSTAINABILITY?

ENGINEERING STUDENTS SUSTAINABLE DEVELOPMENT AWARENESS IN FRANCE

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ABSTRACT

There is no doubt that sustainable development (SD) education is crucial for achieving the UN Sustainable Development Goals (SDG) and we believe that engineering students are important actors for developing SD actions. However, we have few information about how engineering students think about SD issues. The papers aims to investigate engineering students' sustainability awareness in the prism of the SDG. This is a key point in order to design well suited multi- or transdisiplinary curriculum in engineering education so as to develop their awareness of the key role they have to play. We applied an online quantitative survey to French engineering students at first year master level just before starting their specific courses in SD and entrepreneurship. This survey covered different dimensions: SD awareness, SD perception and actions towards SD. Our primary findings show that engineering students mostly associate SD to environmental end economic aspects related to technology (e.g.: renewable energy, low energy consumption, recycling or zero waste) and pay less attention to social aspects like social responsibility and partnership. They consider SD is very important at the global and national level but less important in their professional or personal life. They are reluctant to integrate SD actions in their everyday practice mainly because of

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lack of convenience or financial constraints.There is thus a room for raising their awareness about the central role of engineering in SDGs achievement and their understanding about the social impact of engineering. It would also worth putting more emphasis on social responsibility in their engineering curriculum.

1 INTRODUCTION

In 2015, the United Nations introduced 17 Sustainable Development Goals (SDG), including challenges of poverty, inequality, climate change, environmental degradation, peace and justice; for creating a better and more sustainable future for all by 2030. These complex and interconnected sustainability challenges are closely related to engineering disciplines and give numerous new perspectives to the engineering profession. Without any doubt, engineers will play a fundamental role in achieving these sustainable development goals. As a consequence, sustainability awareness of engineering students who will became engineers in some years is essential for meeting these goals successfully. We would like to investigate what do engineering students know about SDG challenges and what are their SD perception and actions.

2 LITERATURE REVUE

There is a growing number of study in educational literature about students' sustainability awareness in general but less in engineering education in particular. This is quite surprising given the central place of engineering body in sustainability development.

What does knowing and understanding sustainability mean? For Carew and Mitchell [1, pp. 352], an expert-like understanding of sustainability is 'to have factual and theoretical knowledge of sustainability, the ability to apply that knowledge appropriately to contextualized decision-making, and be adept at judging the ethics and sustainability of one's decisions and decision outcomes'. They make a clear separation between the elements of content knowledge (declarative knowledge as the factual knowledge relevant to discipline and theoretical knowledge as the abstract form of declarative knowledge) and structural knowledge (including procedural knowledge, conditional knowledge and critical thinking). There is a learning hierarchy to acquire sustainability understanding: the acquisition of structural knowledge could start only after the successful acquirement of content knowledge. Accordingly, the inclusion of content knowledge as an essential prerequisite of the structural knowledge, should be very important in the engineering curriculum.

According to Azapagic et al. [2], engineering students have a relatively low level of knowledge and understanding about sustainable development and have difficulties to associate sustainability development with engineering practice. Even so, it is encouraging that they have a positive attitude towards sustainability development. Another interesting finding is that they consider it important at their personal level even if it concerns mainly the future generation.

In line with these findings, the empirical study of Kagawa [3] confirmed that students associate the concept of SD with the environment in a unidimensional view rather than applying a multidimensional view including his economic and social dimensions. Concerning sustainability changes in their personal lifestyle, they privilege consumer actions like using of public transportation, changing purchasing habits, recycling or saving energy or water. Similarly to previous studies [4, 5], Nicolaou et Conlon [6] found that engineering students have a deficient knowledge and understanding about sustainable development, more particularly about the social dimension of it.

3 METHODOLOGY

For answering our research question, we carried out a quantitative online survey with closed questions. This survey covered engineering students at Master level in electronics and physics engineering in a French public engineering school. In our initial research design, our intention was to survey engineering students in two steps:

1. For a first time, just before starting their specific SD courses and
2. At the end of their courses, for measuring changes in their sustainability awareness.

Finally, due to unexpected circumstances (exceptional school closing due to world-wide pandemia), we were able to complete only the first survey but not the second one. The courses that were designed partly in flipped classrooms could not take place in a proper way actually during the lockdown. For this reason, our adjusted objective for this survey is to investigate the initial sustainability awareness of the engineering students.

In total, 73 engineering students (composed of 22% female and 78% male students) completed the online survey just before the beginning of their first SD courses developed in the framework of a French national working group of sustainability education [6]. Before the beginning of the survey, students received detailed information about the objective of the survey, the applied confidentiality policy, the storage and use of data as well as the possibility of withdrawal.

Our online survey included the following questions about students':

- knowledge and understanding of sustainable development (four questions),
- previous sustainability education (three questions).
- perception of sustainability (two questions) and
- attitudes towards SD (two questions).

All questions were designed as closed questions for facilitating the data analyses. Before launching our online-survey, we made a pre-test with 10 students (separate from the 73 students mentioned before), asking their feedbacks, allowing us to improve our survey design.

Initially, we planned to make advanced statistical analyses on collected data. As we have a limited sample size and numbers of data, we opted finally to analyze our data with descriptive statistical analyses.

4 RESULTS

4.1 Sustainable development awareness

When asking to students how relevant they would consider the importance of taking economic, or environmental or social actions toward SD, we found that 87% of surveyed students considered these actions either important or very important.. This is a promising result showing students understanding of the importance of SD in their current and future life, even if there are strong differences when their perception of SD is analysed deeper in details, as will be shown in section 4.3.
Concerning their source of information, it was not surprising that surveyed students' main source of information about SD is Internet. Education was at the second place, next to the media, which is encouraging from our educational view.

Table 1 : Source of information considered as significant

A certain teacher	Parents, Siblings	Friends, acquaintances	Education	Media	Internet
33 %	**41** %	**56** %	**69** %	**69** %	**90** %

Regarding their SD education, 71% of the surveyed students considered it was a basic one, which took place indeed mainly during primary and secondary school. Only a very little percentage of students (5%) attended specialized courses on SD in general, or during higher education. This is confirmed by their poor knowledge of SDGs as shown in table 2.

Table 2 : Percentage of engineering students who have some knowledge or know a little bit about SDGs.

SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
%	**33**	**41**	**42**	**55**	**49**	**59**	**53**	**32**	**33**	**48**	**39**	**53**	**50**	**27**	**27**	**34**	**21**

SDGs definition: 1 No Powerty, 2 Zero Hunger, 3 Good Health & Well Being, 4 Quality Education, 5 Gender Equality , 6 Clean Water & Sanitation, 7 Affordable & Clean Energy, 8 Decent Growth & Economic Growth, 9 Industry Innovation & Infrastructure, 10 Reduced Inequality, 11 Sustainable Cities & Communities, 12 Responsible Consumption & Production, 13 Climate Action, 14 Life Below Water, 15 Life on Land, 16 Peace, Justce & Strong Institutions, 17 Partnerships

From Table 2, we observe first that the SD knowledge of the surveyed students is quite restricted. With the exception of quality education, it is focusing on environmental aspects like climate actions, clean water, and clean energy. Second observation is that SDG 9 (industry, innovation and infrastructure), which should highly concern engineering students, is poorly known, even 29% of them never heard about it. Other surprising result is that SDGs 1, 5, 8 and 10, which are social aspects of SD, are also quite poorly know. We also noticed that SDG 17 (partnerships) is the worst known SDG, even 48% of students never heard about it.

These last two observations are somehow surprising for engineering students who are taught to collaborate, co-create and share their work.

Finally, our last but encouraging observation is that engineering students are incline to develop their SD knowledge and understanding: 80% of surveyed students consider that SD education for engineering students is important or very important.

4.2 Sustainable development perception

Our findings depict an important discrepancy in the surveyed students' perception about the importance of SD in the society, as shown in the table 3. On one side, at the macro level of the society, surveyed students considered SD as crucial for the the world-wide society, and relevant only at a country-level. On the other side, at their individual level, they give smaller importance of SD for their professional life and even less for their personal life. This low consideration of SD at their individual level is also contradictory to the fact that SD is considered as crucial for future generation. This is as if they were not aware that they are bound to become key actors of SD achievement.

Table 3 : Rating of the importance of SD

Personal life	Professional life	Country	Society world-wide	Future generation
23 %	**30** %	**53** %	**66%**	**75** %

4.3 Actions towards sustainable development

Regarding engineering students' day-to-day actions and engagements at their personal level towards SD (like transportation, energy and water consumption, waste management or purchasing habits) our findings are not really encouraging and confirm the low importance of SD for the students at their personal level.
The most common action, for nearly all surveyed students, is collecting waste selectively. This is not surprising as it is obligatory in France. At the second place, all kind of actions for decreasing their energy consumption. Which is consistent with the fact that 60% choose an environmentally friendly transportation.
We observed a lack of engagement concerning surveyed students' purchasing habits (66% never or occasionally buy energy-efficient devices, 64% never or occasionally buy products with an environmental label, 56% never or only occasionally reduce the use of disposable product and 52% never or occasionally buy local products). This lack of engagement in their purchasing habits seems to be contradictory to their environmental awareness but could be explained by the fact that simple convenience or financial reasons are the main reasons preventing them from living in a more sustainable way. This is consistent with our finding that 49% of surveyed students have the feeling that the conditions to have an environmentally friendly lifestyle are not easily available.

5 CONCLUSION

As the main conclusion of our study, our findings confirm that surveyed French postgraduate engineering students have a limited knowledge and understanding of SDGs. As a matter of fact, many of SDGs are totally unknown to them. In line with previous studies [2,3,6], they associate SD to its environmental and economic aspects and ignore social aspects like responsibility or partnership that should be very important for practicing their future engineering profession.

They are convinced that SD is fundamental for our planet and for their own country but have a lack of awareness of its impact in their professional and personal life, in contradiction with the results of the previous studies [2, 6]. Conforming to this, they have limited SD actions and engagements at their individual level in their everyday life. However, this low level of engagement could be partially explained by convenience or by their limited financial conditions.

Our findings are very encouraging from an educational perspective. This is confirmed by the strong interest of the students in having not only basic SD education focusing on the acquisition of declarative knowledge but also more extended and comprehensive SD education. The inclusion of social aspects of SD, more specifically social relationship and responsibility, in multi- or transdisciplinary SD education framework would be interesting.

The limits of the present study include the relatively low sample size, the limited engineering disciplines (the surveyed engineering students are studying electronics and physics engineering), the educational level (only postgraduate students) and finally the lack of a second survey after their SD courses.

Future research conducted on more representative samples of engineering students from different engineering domains, but also involving students from different curricula such as management, law, etc., and from different countries are in perspective. As well as, a second survey at the end of specific SD courses should be carried out for assessing the influence of these courses on the SD awareness of the students.

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COLLABORATIVE COURSE DESIGN IN ENGINEERING EDUCATION – A CASE STUDY OF TEACHERS' DESIGN PROCESS

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ABSTRACT

Due to changes of the labor market and increased competition on an (inter)national scale, institutions of higher education are forced to innovate, creating an additional need for teacher professional development. In engineering education, interdisciplinary education has become increasingly important, bringing many advantages for both students and teachers. Instead of being individually responsible for a course, teachers collectively design and teach courses that integrate their areas of expertise and make interdisciplinary education a reality. However, to better support teacher teams and their professional development, higher education institutions require more information on their course design processes. This case study compares the course design processes of two teacher teams in the context of a university-wide educational innovation. One team chose to create an interdisciplinary course, whereas the other chose to design a multidisciplinary course. Design conversations of these teams were analyzed to study the similarities and differences between both teams concerning the design topics and design acts shown during team meetings. Our findings show that both teams primarily focus on the same three design topics: the teaching practices, course organization, and their own teamwork. Other important topics such as the specific characteristics of the student population were mostly neglected. When comparing the specific design acts of the two teams, the interdisciplinary team more often engaged in collaborative planning and adaption of the course and also engaged in more collective reflection compared to the multidisciplinary team. In doing so, the interdisciplinary team created more opportunities for professional development of its team members.

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1 INTRODUCTION

1.1 Collaborative course design to further educational innovation

There is an ongoing demand for higher education to change its focus from monodisciplinary education focusing on one discipline at a time to educational approaches that integrate different disciplines such as in interdisciplinary or thematic education. This demand is placed on both graduate and undergraduate education, for example in engineering, health care, or business.[1-2] Changes of job market requirements and increased (inter)national competition between universities makes educational changes necessary.[2] For engineering education, interdisciplinary education has for example become increasingly important to meet the changing job-market needs.[3] The challenges for higher education not only call for pedagogical changes, but also changes in the way education is designed. Teachers in Higher Education, being used to a high degree of autonomy, are more and more required to work together in multidisciplinary teams, and collaboratively design courses that allow for the integration of various disciplines.[4] Collaborative curriculum design has been shown to be an effective strategy for ongoing educational renewal and corresponding professional development of the teachers involves.[5-6]

However, it is one thing to promote collaboration among highly qualified academics, it is quite another to succeed in practice. Collaborative course design practices confront teachers with major challenges.[5] A planned innovation may result in completely different outcomes as originally intended. The design process of any new course requires making many decisions about the content and teaching methods of the unit, as well as practical decisions regarding organization and scheduling. This holds for both individual teachers as for teacher teams. Practical decisions may feel as more pressing matters and may put off the importance of taking pedagogical decisions. Consequently, intended changes or innovations are not implemented as planned, resulting in conservative courses: the innovation failed because of urgent other matters.

The present study unwraps essential conditions of the course design process conducted by teacher teams engaged in innovative course design in undergraduate engineering education. We focus on collaboration within teams by assessing design conversations topics, the cognitive demand of specific design tasks, and the evolution of these topics and design tasks over time. This study aims to provide a clearer understanding of how multidisciplinary teacher teams can prepare and provide education that better prepares students for the complexity of their future profession and also supports the necessary professional development of the teachers involved.

1.2 Conceptual framework

As is the case with any design process, the design cycle of a new course requires teacher teams to go through the stages of preparation (phase 1: planning), teaching (phase 2: enactment) and evaluation (phase 3: reflection). During each stage,

teachers discuss various *design topics* that involve the content and teaching methods of the course on the one hand, and the organization of the unit on the other hand.[7] Finally, when discussing important design topics, teams engage in various task-related actions, which we refer to as *design acts*. These design acts can be divided into five categories of increasing cognitive demand (see Figure 1). Design discussions of teacher teams should involve higher level design acts to ensure that important topics are discussed with sufficient depth.

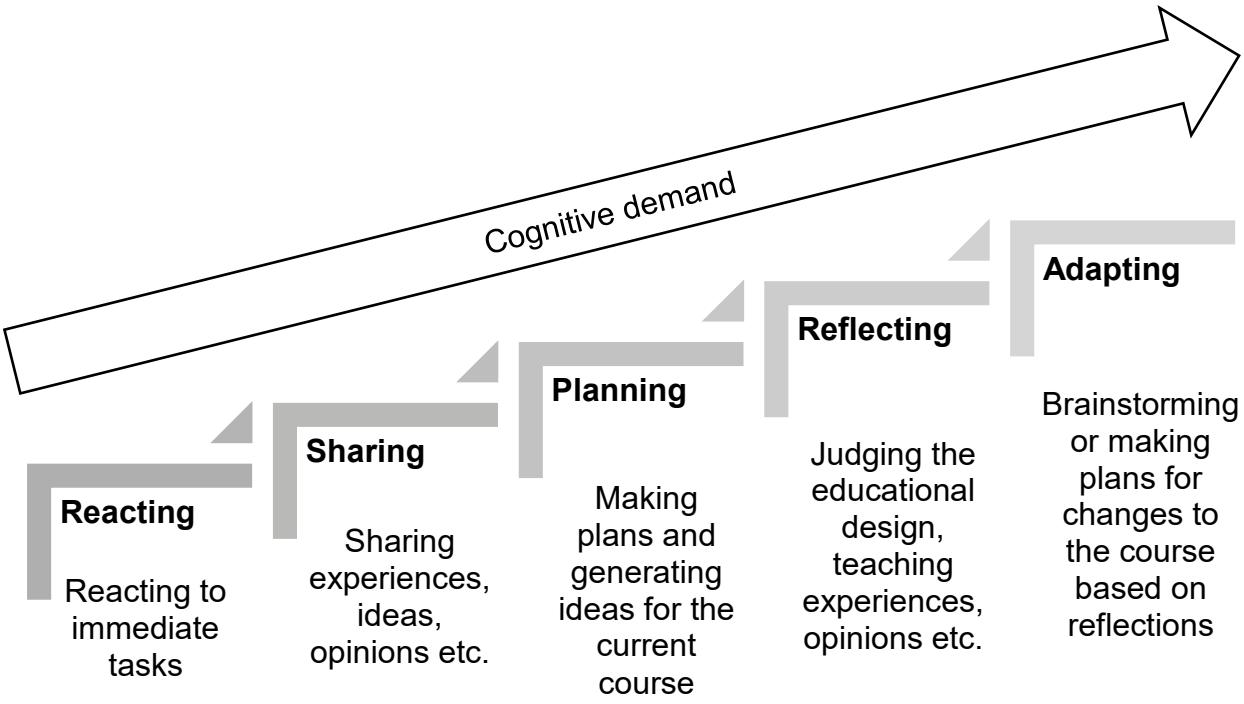

Fig 1. *Higher and lower levels of design acts in teacher teams*[7-8]

A collaborative design process can be challenging as failing to keep to the steps of the design cycle, to focus on all important design topics and to engage in higher level design acts, will ultimately threaten educational change as well as the professional development opportunities of the team members.

The design cycle: During each stage of the design cycle, teams have to overcome various challenges that are related to the design topics and the design acts they perform. For example, teams need to make sure not to prioritize practical decisions over pedagogical needs (1st phase), to monitor their design and allow themselves to adapt it to the needs of the students (2nd phase), and to employ a meta perspective and critically reflect on their own design and implementation (3rd phase). However, keeping to this design cycle can be a problem for teachers who lack the knowledge and/or skills to do so. Research has shown that design conversations are often shallow, and limited by a lack of design skills.[9]

Design topics: During collaborative curriculum design, multidisciplinary teacher teams need to discuss a variety of design topics. They not only need to decide on the content of their course, but also on the teaching or assessment methods they want to use. In doing so, they have to make sure that they meet the needs of the student population. However, previous research in secondary education has shown that teachers have a tendency to focus more on urgent and pragmatic components of a curriculum, neglecting the pedagogical basis for their design decisions.[10] For innovative teams this could mean missing the point of the innovation (adapting the content and methods of the course to the changed needs of students and the job market) completely.

The design acts: Instructional design involves a high level of precision and expertise, is cognitive demanding and requires higher order thinking skills (see Figure 1). Research has shown that cognitively demanding conversations are not only crucial for the design of a new course (as important issues are discussed with sufficient depth), they also create valuable learning opportunities for teachers.[7] When teams do not engage in higher level design acts such as collective planning by building on each other's knowledge, interdisciplinary education will fail as teachers are not able to truly combine their disciplines and further develop their educational design.

A shift from traditional monodisciplinary education to interdisciplinary education is difficult to make. It requires that teacher teams are supported in this endeavour.[1] However, research on educational design issues in the domain of education seems to be missing. It is therefore crucial to zoom in on teams' design conversations to determine how teams can best be supported. The present study examines the following three questions:

1) *What topics are discussed during teacher teams' design conversations?*
2) *How do types of design acts vary among the different topics of the design conversations?*
3) *How do types of design acts vary in relation to the topics of teacher teams' design conversations during the phases of the teams' design cycle?*

2 METHODOLOGY

2.1 Setting

The present study was conducted at a Western European university that had recently introduced a curriculum innovation for all bachelor programs in the university, making the step from traditional lecture-based education to project-based education. This innovation required teachers for the first time in their careers to work together in teams to design new courses. These courses put a student project at the core of the course, supported by lectures, tutorials etc. Twelve teacher teams were formed for each bachelor programme. [11] Teacher teams had a high degree of autonomy in designing the new course with respect to course contents and choice of teaching methods. The teams were required to create courses that included a central project

and integrated various disciplines. However, the specific design of the course was left up to the teacher teams.

2.2 Sample

Two teacher teams, one from the civil engineering and one from the applied mathematics study programs, both consisting of six teachers, participated in this study. The teams also included teachers from other disciplines such as governance studies and educational sciences, respectively. The members already had several years of teaching experience. Each team was assigned a designated team leader. Both teams were among the first to design integrated courses at this university. The teams were selected for the study based on the comparable amount of team meetings during the course design cycle.

2.3 Analysis

Team meetings of both teams were audiotaped and transcribed. The transcripts were divided into meaningful utterances (i.e. one speaking turn) and coded regarding the topics and design acts involved. A total of 10 different design topics were deductively and inductively coded: Pedagogical knowledge, content knowledge, pedagogical content knowledge, scheduling, teamwork process, student population, student feedback, student learning and off topic (see Table 1). All five design acts (Reacting, Sharing, Planning, Reflecting, Adapting) were coded. The inter-rater reliability of .87 (Cohen's Kappa) shows the validity of the findings. To answer the research questions, the percentage of utterances of each design topic was calculated, followed by the percentage of design acts per topic. Finally, the percentage of topics per design act was calculated for each phase of the design cycle. Based on these calculations, the design processes of both teacher teams were compared.

3 RESULTS

Providing the teacher teams with a high amount of freedom concerning the design of the new courses led to two different educational approaches. Whereas team A chose to create an interdisciplinary educational module, team B chose to create a multidisciplinary module.[3] In the interdisciplinary module, various disciplines and a project where closely integrated. In the multidisciplinary module different disciplines were added to one another instead of being integrated. When looking more closely at the design conversations of both teams, some similarieties but also important differences can be seen concerning the design process.

In both teams, the vast majority of utterances involved *pedagogical content knowledge* (e.g. talking about aligning the content of the course with suitable assessment methods) followed by *scheduling* of teaching activities and talks about the *teamwork process* of the teacher team itself (see Table 1). Other important design topics such as the student population or discussions about how student learning can best be supported were (mostly) neglected.

Table 1. *Percentage of utterences spend on various design topics*

	Pedagogical knowledge	Content knowledge	Pedagogical content knowledge	Teaching values	Scheduling	Teamwork proces	Student population	Student feedback	Student learning	Off topic
Team A: Interdisciplinary	8%		56%		14%	12%				
Team B: Multidisciplinary			35%		23%	19%		9%		

Note. Only results above 5% of utterances are reported; percentages were rounded.

Furthermore, when comparing the two teams, the results show that design acts varied greatly between both teams as well as among design topics. Team A engaged in more higher level design acts (reflecting and adapting) than team B. For both teams, and especially for team A, higher level design acts were mostly connected to the topic of pedagogical content knowledge (see Table 2 & 3).

Team A also engaged in reflecting and planning for the topics of scheduling and the teamwork process itself. Other topics were not discussed with this level of cognitive demand, limiting the learning opportunities for team members of both teams. Crucial topics such as the student population were almost never discussed and if they were discussed, the conversation involved low cognitive demand. The fact that team A engaged in more higher level design acts compared to team B could be explained by the different educational approaches of both teams. Whereas the goal of a high level of integration of different parts of the course asks for a more collective planning (Team A), the multidisciplinary design of the course of team B involving more separate unit components made it easier to divide tasks and not engage in collective design acts of a higher cognitive level. As shown in the case of team B, this practice can be problematic as it withholds teachers from in-depth conversations and is therefore a missed learning opportunity for them. Furthermore, combining disciplines to reach interdisciplinary education becomes difficult and the educational innovation is not implemented as intended.

Finally, for team A the level of design acts involving pedagogical content knowledge also increased during the design cycle (see Table 2). The design acts of other design topics however stayed on a low level during the whole design cycle. Team B showed no actual increase in level of design acts during the design cycle (see Table 3) apart from some reflection in the second phase. Especially the lack of the higher level design acts of reflecting and adapting in the third phase of the design cycle is apparent.

Table 2. *Percentage of topcs per design acts per phase of the design cycle: Team A (interdisciplinary)*

Phase of design cycle	Design act	Pedagogical knowledge	Pedagogical content knowledge	Scheduling	Teamwork process
1st Phase	Reacting	8%		9%	14%
	Sharing	18%	9%		7%
	Planning		22%		
	Reflecting				
	Adapting				
2nd Phase	Reacting			7%	
	Sharing		11%	5%	
	Planning		51%		
	Reflecting		6%		
	Adapting				
3rd Phase	Reacting				
	Sharing		18%	7%	
	Planning				
	Reflecting		16%		
	Adapting		21%		

Note. Only results over 5% of utterances are depicted; percentages were rounded.

Table 3. *Percentage of topcs per design act per phase of the design cycle: Team B (multidisciplinary)*

Phase of design cycle	Design act	Pedagogical knowledge	Pedagogical content knowledge	Scheduling	Teamwork process	Student Feedback
1st Phase	Reacting			16%	15%	
	Sharing	6%	23%	16%	6%	6%
	Planning					
	Reflecting					
	Adapting					
2nd Phase	Reacting				8%	
	Sharing		36%			12%
	Planning					
	Reflecting		10%			
	Adapting					
3rd Phase	Reacting				7%	
	Sharing		30%	27%	17%	6%
	Planning					
	Reflecting					
	Adapting					

Note. Only results over 5% of utterances are depicted; percentages were rounded.

4 SUMMARY

The results show that independent of the educational approach chosen, it is difficult for teams to engage in higher level design acts. However, for some topics such as pedagogical content knowledge a cognitively demanding discussion might come more natural than for other topics. Furthermore, a more interdisciplinary teaching approach makes the engagement in discussions involving higher level design acts (such as collective planning, reflecting and adapting) necessary, whereas this is not necessarily the case for a multidisciplinary teaching approach. This study shows that teacher teams have the potential to support the shift from monodisciplinary education to interdisciplinary education as it is demanded from both undergraduate education as well as from professional education. When teacher teams meet the right conditions, teachers can learn from each other and truly combine their disciplines in new courses that better prepare students for the new demands of the job market. However, although literature on professional education is pleading that collaboration of teachers (and other stakeholders) can make interdisciplinary education a reality, this study shows that this is not easily done. Teachers often lack design experience and tend to prioritize specific design topics while neglecting others and miss their chance to engage in collective reflecting and adapting. However, compared to a multidisciplinary teaching approach, interdisciplinary teaching opens opportunities for teachers to share and build new courses together. In doing so, teachers can create valuable learning opportunities for themselves. A multidisciplinary teaching approach on the other hand seems to hold the danger of teacher teams missing out on valuable collective design opportunities as well as opportunities for their own professional development.

Previous research has shown that teacher teams benefit from the support of a facilitator, which might also be the case here.[12] Team leaders can also play a crucial role in creating cognitively demanding design conversations that benefit the design of the course as well as the professional development of the team members.[1] This however requires a preparation of the team leader for the leadership role that focusses on both the design topics that need to be discussed and the skills that are needed to foster cognitively demanding discussions. Furthermore, teams need to be exposed to robust design processes as a good example for their own teamwork. It has become clear that universities cannot expect teams to engage in innovative design processes without supporting them in this endeavor.

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DESIGN GUIDELINES FOR LABORATORY LEARNING ACTIVITIES IN STRUCTURAL MECHANICS

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ABSTRACT

Structural Mechanics (SM) is a fundamental subject in engineering bachelor curricula. Since experimental investigations play a central role in the discipline, laboratory practice is often present in SM courses. Many instructors recognize in laboratory activities, not only a way to develop laboratory skills and appreciation of the scientific method, but also a chance to reinforce students' conceptual understanding of the discipline. However, there is evidence that laboratory instruction is not always successful in achieving conceptual understanding.
To address this problem, the goal of the presented study is to investigate how laboratory activities can be designed to support students' conceptual understanding of SM. First, the disciplinary body of knowledge is analysed through Johnstone's model of multilevel thought. In SM, as in Physics and in Chemistry, phenomena are analysed at different scales: the phenomenological level, the invisible level, and the symbolic level. The understanding of most Structural Mechanics concepts relies on linking the phenomenological world to the underlying invisible world using symbolic representations such as equations, diagrams, experimental data plots, and physics models. To transition and translate between "levels of thoughts" and understand SM

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concepts, representational competence and abilities in model-based reasoning are needed. In the next paragraphs, a review of successful studies from similar subjects is presented, where the learning activities targeted representations and model reasoning in laboratory settings. The findings are summarised in a set of design guidelines to help instructors develop successful laboratory learning activities for SM.

1 INTRODUCTION

1.1 Problem analyses and research question

This paper explores the design of instructional laboratory practice for the discipline of Structural Mechanics (SM), a fundamental subject in bachelor engineering curricula. Laboratory practice is of central importance in the engineering professions in general. Specifically, experimental data are needed in the characterization of materials, in the design of new products, and to measure design performances [1]. Laboratory practice is also a fundamental part of knowledge creation in SM. Although research is mainly carried out through simulations and computational methods, new models and theories are validated experimentally [2]. Students are expected to acquire practical laboratory skills as well as the ability to design and conduct experimental investigations to be ready for their future professions. To fulfil these requirements, laboratory practice is often present in SM undergraduate curricula, either as a stand-alone course or integrated into lecture-based courses.

The complexity and the high level of formalism of Structural Mechanics tend to hinder students' understanding of disciplinary concepts [2]. Therefore, many instructors recognize in the experimental practice also a chance to reinforce students' conceptual understanding of the discipline [3]. However, there is evidence that laboratory instruction is not always successful in achieving that aim. In fact, during laboratory practice, students often follow provided step-by-step procedures focusing on procedural issues rather than elaborating on the disciplinary concepts for which the activity was designed. Hofstein and Lunetta already came to this conclusion in a first review in 1982 [4], and their conclusions are still currently valid for many laboratory courses [5]. Nevertheless, there have been also successful initiatives, especially at secondary level science education. For example, the European Labwork in Science Education project [6] provided a framework to reflect on the effectiveness of practical work in science.

Moreover, there are very few studies investigating how laboratory practice can scaffold conceptual understanding in engineering. Specifically, there is a lack of research focusing on instructional laboratories in Structural Mechanics and on the specific challenges linked to Structural Mechanics disciplinary concepts. As a consequence, there is a need for clear guidelines that instructors can use in the design of effective instructional laboratories, useful at scaffolding students' conceptual understanding and applicable in the everyday classroom learning environment. Hence, the main research question that guided the presented study is: "How can laboratory activities support students' conceptual understanding of Structural Mechanics?". The aim is, on the one hand, to define requirements for laboratory instruction in a Structural

Mechanics course, and, on the other, to investigate the link between laboratory activities and conceptual understanding in Structural Mechanics. Design guidelines serve both aims, they provide practical goals for the intervention and they are useful for sharing the theoretical understanding.

1.2 Methodology

In determining the design guidelines, an approach developed by Van den Akker (1999) has been followed, as suggested by Bakker in [7]. The approach consists in the formulation of every design principle in terms of intervention characteristics and implementation procedures, providing theoretical and empirical arguments. In order to define the theoretical arguments, first conceptual understanding is defined, as well as its relationship with models and representations. Secondly, the disciplinary body of knowledge is analysed through Johnstone's model of multilevel thought. Skills necessary to reach conceptual understanding in Structural Mechanics are identified. Successively, discipline-specific challenges that students face are considered, as described by relevant research studies in the domain of SM teaching and learning. Finally, for the empirical arguments, studies that addressed those challenges with laboratory activities in similar domains are presented. Existing recommendations from the literature have also been noted.

2 CONCEPTUAL UNDERSTANDING IN STRUCTURAL MECHANICS

2.1 Conceptual understanding, models, and representations

The revised Bloom's taxonomy [8] defines conceptual understanding as the abstraction from factual knowledge, the understanding of the disciplinary core ideas and principles and their interrelationships. From an epistemological perspective [9], students with a correct understanding of the discipline, have concepts organised and related to each other in a coherent and robust mental model, from which they derive correct reasoning under different circumstances and contexts. In a similar manner, scientific disciplines provide models to describe and explain real-world events and phenomena, and to predict the outcomes of new events. Therefore, modelling is often considered the ultimate goal of science. Scientists generate models using experimental evidence, and they search for new evidence using models. Such intertwining of evidence- and model-based reasoning supports the understanding of phenomena [10].

Models are dependent on a broad spectrum of representations, in order to fully represent the salient characteristics of phenomena and their interrelationships. In fact, every representation affords access to some attributes of the phenomenon and hides some others. Taken together and coordinated, disciplinary representations provide the opportunity to fully 'see' the phenomenon [11]. Therefore, as Etkina et al. point out [12], effective instruction guides students in achieving representational competence: extract information from representations; translate between types of representations and build one representation from another; use them to construct meaning of phenomena under-study. Hence, modelling and representational competence are

necessary for concept learning. In the next section, the models and representations necessary in the case of Structural Mechanics are described.

2.2 Johnstone's model applied to Structural Mechanics

The discipline of Structural Mechanics (SM) studies the effects of loads on deformable bodies and physical structures. Unlike many scientific disciplines, the purpose of SM is practice-oriented: its knowledge system is meant to be used as a resource in engineering activities, such as the design of structures [2]. The results of the structural analysis are employed to compute deformations and stresses, to predict and avoid structures failure and to evaluate and verify structures suitability for use.

In order to fully describe the structural phenomena, the physical system is analysed at different scales. A useful tool to represent the levels at which phenomena are explained is Johnstone's model [13] of multilevel thought, frequently used in science education and especially in chemistry education [14]. Johnstone's model recognizes three levels of thought in physics and chemistry: the phenomenological or macro level, the invisible or micro level and the symbolic level. Since Structural Mechanics is closely linked to Applied Mechanics and Material Sciences, we argue that this explanatory framework is applicable to Structural Mechanics as well.

As seen in the example in Figure 1, in the analysis of deformable bodies, the physical system is modelled at the phenomenological and at the invisible levels.

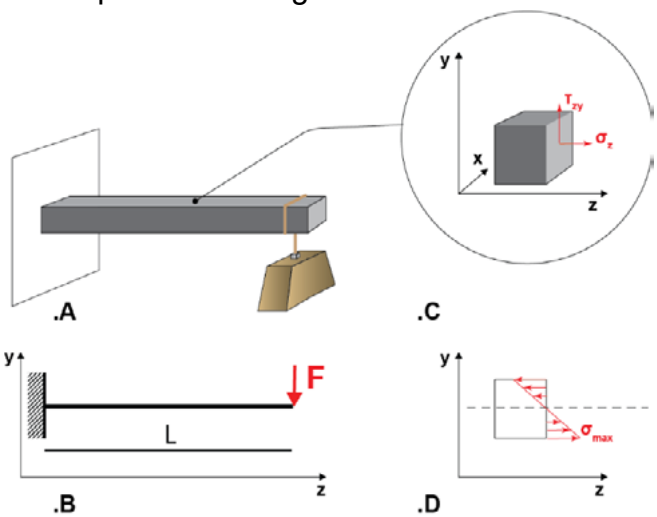

Figure 1- Examples of symbolic representation at phenomenological level (1.A and 1.B) and invisible level (1.C and 1.D)

At the phenomenological level, the observable features of the system are considered, such as the structure geometry, supports, applied loads and displacements. These concepts are formal conceptualisations of processes or features that students can experience directly.

The invisible level in SM is better defined with the term 'local level'. At this level, material properties, internal forces, stresses, strains are considered. Depending on how detailed the analysis is, materials can be modelled as a continuous mass, or considering material micro or nano structure (such as the crystal lattice and/or fibres

and defects). Usually, at bachelor level, the first approach, based on continuum mechanics principles, is followed. Therefore, representations such as the infinitesimal cube (figure 1.c and. d) are used in the analyses [15].

SM provides models that describe, explain, and predict what is observed at the phenomenological level thanks to the integration of local level properties. This is achieved through the coordination of symbolic representations, for instance equations, graphs, free body diagrams. The understanding of most Structural Mechanics concepts such as stress, strain or deformation rely on linking the phenomenological world to the underlying local level using symbolic representations. In many cases, several representations are needed to fully represent concepts and their interrelationships. Therefore, in order to translate between “levels of thoughts” and understand Structural Mechanics concepts, representational competence and abilities in model-based reasoning are needed.

2.3 Teaching and learning Structural Mechanics

Structural Mechanics is often considered a difficult subject, due to the level of abstraction of its symbolic representations [16]. As noted by Kurrer [2], this high level of formalism is intentional. Structural systems have a high degree of indeterminacy and interdependency between variables, so, historically, the solution of complex problems became possible only when new mathematical tools such as calculus and matrix notation were implemented. This new formalism generated new concepts that cannot be directly inferred from experience; in other words, some symbols and relations are not directly linked to physical characteristics of the system. However, this formalism also enabled the solution of complex structural problems by fast manipulations of symbols, without having to interpret the symbols or knowing what they mean.

Because of the complexity of the symbolic representations, instructors and students tend to focus more on formulae and mathematical procedures for problem solving [17], which do not directly afford the visualization of the system behaviour at a phenomenological and local scale. Students become proficient at dealing with the symbolic representations, but they do not connect them to phenomenological and local levels. Therefore, students often acquire the procedural skills needed to pass the exam but fail to grasp the physical reality hidden behind the equations. For example, Montfort et al. [17] studied the development of conceptual understanding from a sophomore-level mechanics of materials class to a graduate-level advanced steel design class. They proved that students in higher-level courses were better at solving problems but did not demonstrate significantly more conceptual understanding than students in the earlier courses, which is a typical result found in many sub-disciplines of Physics and Chemistry.

In a recent study, Brown et al. [16] investigated students’ difficulties of acquiring conceptual understanding of Mechanics of Materials. This research highlighted how students had the abilities to correctly calculate outcomes of phenomena they could not properly explain. Students’ wrong explanations appeared to stem from attempts of linking observable features of the problem (the direction of loads, point of application)

directly to local level features in a rather simplistic manner (for example “the maximum stress is always at the application point of the load”; “normal load only creates normal stresses and shear load only creates shear stresses”.)
The present study recognises that to help students develop proper explanations, instruction should provide different representations, showing the relationships between loadings and stress distributions. Laboratory activities can provide students with the direct experience of Structural Mechanic phenomena, bypassing the analytical formulation scaffolding conceptual understanding.

3 CONCEPTUAL UNDERSTANDING AND LABORATORY ACTIVITIES

3.1 Guided inquiry-based instruction style

Conceptual understanding is the main learning goal pursued by instructional laboratories [3]. However, this kind of laboratory activities is not often successful. In fact, the goal of increasing conceptual knowledge is commonly tackled by verification laboratories, i.e. instruction focused on verifying analytical formulas and theory through experimental observation. Learning outcomes are likely to be influenced by the style of laboratory instruction employed and, as discussed by Holmes et al. [18], verification laboratories tend to be overly structured in an attempt to make students perform the experiment correctly at the first trial. As a result, students blindly follow the provided step-by-step procedure without engaging in the learning process. For this reason, verification laboratories are also called cookbook laboratories [19].
An alternative instruction style is the guided inquiry-based approach, also known as discovery learning, whose central focus is students’ investigative work. The general principle of guided inquiry-based learning is to present students with problems and questions and to guide their curiosity into the discovery of solution and answers [20]. The guided inquiry-based approach has been widely developed in the years, with implementation heuristics being clearly defined [21]. The main ones are:

- Students do not know the outcome of the experiment and are only given the information they need to design and carry out the experiment.
- Students should be actively involved in developing or deciding upon at least some elements of the procedures of the laboratory exercise.
- Students should have opportunities to encounter both positive and negative results.
- Students’ learning is guided with questions for discussion and reflection on the implications of the experiment they perform or the data they collect.

3.2 Model-based reasoning and representational competence

Von Aufschnaiter & Von Aufschnaiter [22] brought new evidence in support of the inquiry-based approach, studying conceptual understanding and model-based reasoning in higher education instructional laboratories. Their research aimed at characterising the learning process taking place in a laboratory setting, video recording several different students’ activities within typical laboratory instructions. They observed that whenever laboratory instruction tries to ‘inform’ students about the theoretical model and symbolic representation at an early stage in the learning

process, students make no use of that information. Less than 10% of the time spent in the laboratory is usually given to explicit discussions of concepts or conceptual reflection on practical activity. Instead, students tend to first explore tool functions and find the shorter way to the numerical result. From these results, Von Aufschnaiter & Von Aufschnaiter suggest that laboratory activity designed to promote learning of unfamiliar concepts should not focus explicitly on the symbolic level at the beginning. Instead, instruction should facilitate experiences at the phenomenological level, as these are a prerequisite for students to arrive at an understanding of the phenomena based on their observations. Thus, post-processing should be the phase when students integrate their experiences in the laboratory with physics concepts.
Bernhard et al. [23] argue that the fundamental purpose of laboratory work in physics and engineering is linking theory (symbolic level) to experimental observations (phenomenological and local level). Because of the complexity of the learning environment, it is difficult to see and analyse how students perform those links and construct their understanding. Therefore, Bernhard et al. developed an analytical tool to study student learning in the laboratory, the "learning of complex concepts model", reported in Figure 2.

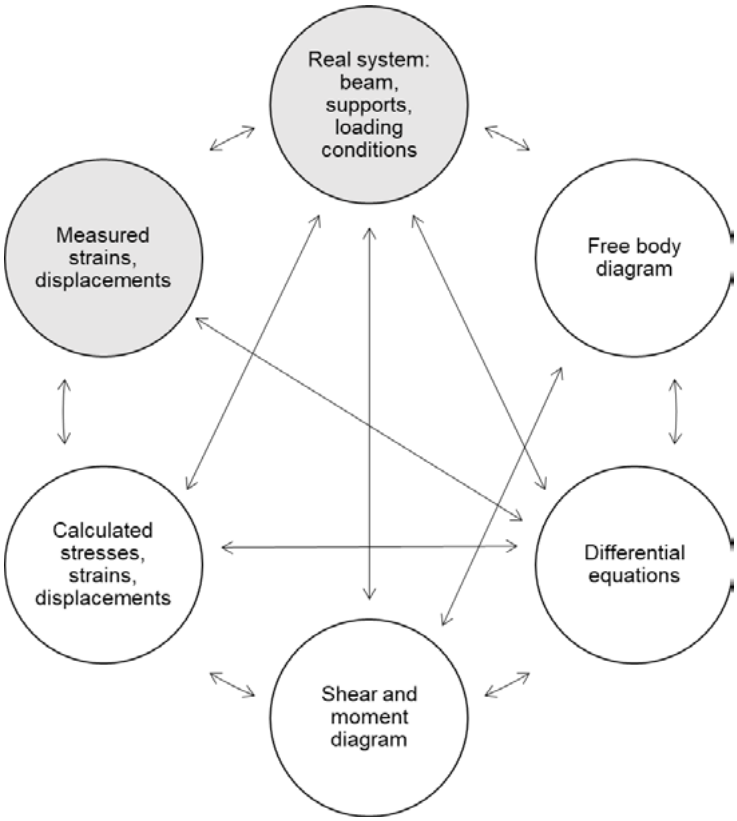

Figure 2- An example of an analysis of learning in a laboratory on the topic of bending of the beam, using the model for learning a complex concept

First of all, the representations that an expert would use in performing the experimental task are identified and illustrated by circles. Representations are divided into two groups, one pertaining to the experimental evidence, which in Figure 2 are coloured in light grey, and the other pertaining the analytical model, coloured in white. Through

model-based (mathematical transformations, physical modelling) and evidence-based reasoning (collection of data, interpretation, qualitative judgment) experts translate from one representation to the other in order to analyse the experimental results [24]. These links are represented with arrows between the circles. As a result, an ideal path through the representations is identified, upon which the instructional laboratory activity is built. Students are provided with some representations; they are guided by assignment questions and cues in producing missing representations and connecting them together. The model can be also used to assess students' work, highlighting the links that students were able to make, either by observing students during the laboratory practice or assessing their lab reports. Moreover, the model can be used to refine the design of the activity, identifying gaps between what students were expected to do and what they actually did.

4 DESIGN GUIDELINES

The findings discussed in previous sections have been summarised in a set of design guidelines that can help instructors in the development of instructional laboratory activities in Structural Mechanics.

1. Prefer the guided inquiry-based style of laboratory instruction over the validation and cook-book approach because it scaffolds students' engagement with disciplinary concepts.
2. Create the opportunity for students to directly observe and experience the phenomenon bypassing the analytical model, because this allows students to arrive at an understanding of the phenomenon based on their observations. Ask students to link observed episodes to the theoretical propositions only in a post processing phase.
3. Develop data processing tasks based on the use of different representations, such as free body diagrams, infinitesimal cube, load-displacement plots, and strains distributions. Many representations beyond formulae are needed to fully characterise what happens at local level and the events visible at the phenomenological level.
4. Ask students to analyse data linking the observed physical events at the phenomenological level to the theoretical propositions at the symbolic level. Guide students in extracting information from representations; translating between types of representations and build one representation from another. This helps students intertwine model and evidence-based reasoning and expanding their understanding of concepts.
5. Track how students move from experimental data and analytical model during data processing because this provides feedbacks on how students construct meaning of the phenomenon under-study and on the effectiveness of the laboratory activity.

5 DISCUSSION AND CONCLUSIONS

To answer the research question: "How laboratory activities can support students' conceptual understanding of Structural Mechanics?", first a definition of conceptual understanding is provided, highlighting the importance of representational

competence and modelling in understanding science. Then, the body of knowledge of Structural Mechanics has been analysed with Johnstone's model of multilevel thought, discussing how representational competence and abilities in model-based reasoning are needed to translate between "levels of thoughts" and understand Structural Mechanics concepts. These theoretical lenses have been used to study students' difficulties at learning Structural Mechanics, identifying the main issue as linking the symbolic representations, especially the analytical model, to the underlying physical phenomena.

Then possible ways in which this issue can be overcome in laboratory settings have been addressed. Inquiry-based instruction helps students engaging in the process of constructing meaning of physical phenomena. Von Aufschnaiter & Von Aufschnaiter suggests to first let students experience the phenomenon without the mediation of the symbolic representation. The experimental observations can be linked to the analytical model in the post processing phase. Bernhard et al. developed a model to track the links students build between the phenomenological word and the symbolic representations.

These findings are summarised in a set of design guidelines to help instructors develop successful laboratory learning activities for Structural Mechanics. The design guidelines are grounded in the Structural Mechanics domain and the specific challenges students face learning it. However, the same procedure can be followed to develop design for other domains.

The presented analyses are the first step of a design-based educational research project, in which the presented framework will be used for the design of a laboratory activity in a real Structural Mechanics classroom setting. Validation, feasibility, and robustness of such guidelines will be tested in a subsequent design iteration, having the design guidelines do real work in educational practice. This will be the first trial and test, consequently and informed by evidence and experience, the design framework could be edited and refined.

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IMPROVING LEARNING OUTCOMES OF SMALL GROUPS WORKING ON AN ENGINEERING DESIGN-ASSIGNMENT DURING LECTURES

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ABSTRACT

In the past years, the interest in collaborative learning has increased substantially. However, despite the attention for collaborative learning and the existing body of knowledge on that topic, many lecturers experience problems when implementing collaborative learning. Consequently, the theoretical benefits of collaborative learning are not always achieved in practice. To address this gap, this research studied higher education students collaborating on an engineering design-assignment during lectures, as a form of collaborative learning. The specific research question was: how can lecturers improve learning outcomes of small groups working on an engineering design-assignment during lectures? The research is a design-based research, aimed at systematically investigating problems, and designing and evaluating solutions to improve lecturers' actions and education. Five groups were videotaped when working on an assignment and the learning outcomes of those groups were assessed. Then, problems were analysed and possible solutions to improve learning outcomes were developed. The solutions had the form of practical interventions that lecturers could apply straight away. The interventions were evaluated by applying them to treatment groups and comparing their learning outcomes with those of control groups, which were not subjected to interventions. The results revealed that for most of the groups to which the interventions were applied, learning outcomes were better. However, there were also exceptions. Further analysis was needed to explain these. This research is relevant for lecturers who apply group work in their lectures because it reveals some mechanisms behind collaborative learning, and provides insight in variables that can be adjusted for further improvement.

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1 INTRODUCTION

1.1 Research background and objective

In the past years, the importance of collaborative learning has increased substantially. Collaborative learning can be defined as instruction that involves students working in teams to accomplish a common goal, under conditions that include team members' interdependence, individual accountability, face-to-face promotive interaction, the use of collaborative skills, and group processing [1, 2]. Collaborative learning can take many forms such as students working together on projects, Problem-Based-Learning and Team-Based-Learning. Collaborative learning has gained importance in higher education because of its effectiveness. Among others, collaborative learning tends to exhibit higher academic achievement, greater persistence through graduation, better high-level reasoning and critical thinking skills, and deeper understanding of learned material [3, 4].

Many lecturers acknowledge the importance of collaborative learning and apply this in some form in their courses, but despite the attention for collaborative learning and the existing body of knowledge on that topic, many lecturers experience problems when implementing collaborative learning. Consequently, the theoretical benefits of collaborative learning are not always achieved in practice. To address this gap between theory and practice, this research studied higher education students collaborating on an engineering design-assignment during lectures, as a form of collaborative learning. The specific research question is: how can lecturers improve learning outcomes of small groups working on an engineering design-assignment during lectures? The corresponding goal of this study is to develop interventions to improve the learning outcomes of small groups working on an engineering design-assignment during lectures. This research is relevant for lecturers who apply group work in their courses because it provides actions to improve learning outcomes and reveals some mechanisms behind collaborative learning.

1.2 Activity Theory as a theoretical framework

In this research, a well-supported theory is used for analysing collaborative learning in groups working on an assignment. This theory is called Activity Theory (AT). The theory is suitable for studying collaborative learning in various learning environments [5]. Moreover, the theory has been used earlier to analyse collaborative learning in design and engineering education and in other learning environments too. In addition, key steps for carrying out research with the use of AT have been formulated [6], and an example of applying this theory in an engineering design setting at higher education is also available [7]. Thus, there is reference material to facilitate a thorough and evidence-based research.

AT assumes that learning should be studied within the context in which it occurs because context and learning are intertwined. AT therefore can be categorised under the heading of the social constructivist learning perspectives. Rather than being a

process of knowledge transmission, knowledge is socially constructed, based on the intentionality, history, culture and tool mediation used in the process. AT helps to understand the subtleties of the collaborative learning process and the dynamics of collaboration between group members.

1.3 Elements of Activity Theory

AT distinguishes six interrelated elements to interpret an activity carried out by a group. The elements are related to one another, forming the AT triangle (Figure 1).

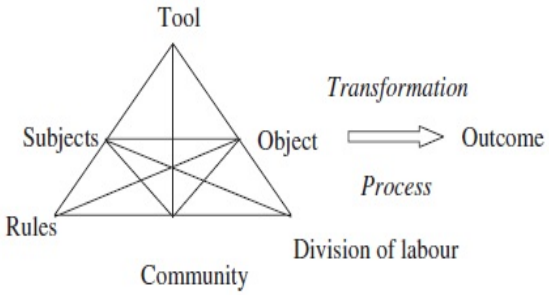

Figure 1 Activity Theory Triangle [6]

The core elements, forming the AT triangle, can be described as follows:

- The subject is the participant in an (learning) activity, motivated towards a purpose or attainment of the object.
- The object describes the problem space at which the subject is directing his or her attention. It is an invitation to interpretation, personal sense-making, and societal transformation. It is the raw material and future-oriented purpose of an activity. The object as such, represents the motives for a subject to engage in an activity. For example, an object can be a certain design task that the student has to complete.
- The outcome is the consequences that the subject faces because of his/her actions driven by the object. This is the 'ultimate goal'. In an educational setting, these outcomes could be passing the course, or getting a high grade.
- Tools are socially shared cognitive and/or material resources that the subject can use to attain the object. For example, the student may use a certain design methodology or strategy (cognitive resources), or a computer (material resource), for achieving the object.
- Informal or formal rules regulate the subject's participation while engaging in an activity. For example, an informal rule is that the student is not allowed to cheat. This is a rule that is not stated explicitly, but students know it is not allowed. A formal rule could be that the activity should be finished within two hours.
- The community is the group or organisation that has a relation with the object and that can influence how the subject behaves. For example, in an assignment in class, the lecturer belongs to the community. In addition, other students or groups that work on the same, or similar, assignment can be part of the community, as they can exert influence.

- The division of labour is the shared participation responsibilities in the activity. For example, the subject/student makes appointments with his/her other team members about the division of tasks and responsibilities

The elements within the AT triangle are related to one another. For example, the subjects (S) could experience that they are not able to work with a specific tool, such as a software program (T). In that situation, there is a tension between S and T. By studying the elements as well as the relationship between the elements of the AT triangle, groups can be analysed, as demonstrated by Zahedi et al. [7]. According to AT, the tensions within and between the elements in the AT triangle can provide the leverage points for improving learning. For example, the lecturer can apply interventions to these tensions. An intervention can be defined as: "*A purposeful action by a human agent to create change*" [8]. AT adopts a perspective of learning that sees the members of the group as actively constructing meaning within a cultural-historical context. Although the group members are conceived of as active, it is the responsibility of the culturally more advanced facilitator (e.g. lecturer) to provide opportunities for acceptable constructions, and to create opportunities for groups to learn.

2 METHODOLOGY

This section describes how the research was carried out. The research is a design-based research, aimed at systematically investigating problems, and designing and testing solutions to improve lecturers' actions and education.

2.1 Step 1 – Data collection

As a first step, the groups working on an assignment during a lecture were observed. This assignment was part of a design course: Course I. The purpose of this step was to understand what is going on in the groups when they are working on the assignment during lectures. The groups were only observed and there was minimal intervention by the lecturer. Observations were done from the perspective of AT, meaning that the elements of the activity triangle were studied [6]. There was one lecturer involved as the main lecturer and another lecturer to assist with the video recordings. The main lecturer was also the researcher. The data collection method used in this step was video recording. This method was used because this allowed the researcher to gather in-depth data simultaneously on multiple groups. Five of the twelve groups in Course I were studied in this step. The groups were first-year university Bachelor students and were randomly selected from all groups in Course I. Each group consisted of 5 to 6 students. Analysis was done in keeping with the approach proposed by Zahedi et al. [7]. Based on an analysis of speech and behaviour in the group, the recordings were tagged with the elements of the AT triangle, using the software program Atlas.ti.

After the AT framework was described and put in a timeline, the learning outcomes were studied. The outcome of the group assignment is a FAST diagram (Function

Analysis System Technique). It represents the functionality of a system with boxes and arrows that connect the boxes. This FAST diagram, as developed by each group, was assessed with an assessment protocol. The basis for this protocol were the learning goals of the assignment. The protocol was validated with a peer-lecturer with knowledge of FAST diagrams. This validation showed that the protocol is robust.

2.2 Step 2 – Data analysis

In the second step, the AT observations and scores of the groups were compared to one another and differences and similarities were assessed. It was also tried to identify patterns. It is relevant to analyse differences, similarities and patterns, because this provides directions for interventions.

2.3 Step 3 – Developing the interventions

In the third step, the interventions were developed, based on the findings of the previous steps. This was a creative step in the research and could not be completely designed in advance, as it was not known beforehand what was exactly going on in the groups. The interventions were discussed with experts and lecturers to validate them.

2.4 Step 4 – Applying and evaluating the interventions

In the fourth step, the interventions were applied and evaluated in another design course: Course II. The interventions were applied to eight groups (all groups in the course). Each group consisted of 5 to 6 students. The students in these groups got a similar assignment as those in Course I – to produce a diagram – but for different projects. The reason for using different projects was that the interventions have to be useful in other courses as well. Nevertheless, the method and underlying theory of the assignment remained the same. Only the project to which the method should be applied was different.

3 DATA COLLECTION AND ANALYSIS

In this section, the results of step 1 and 2 of the research approach are described. This concerns data collection and data analysis of the groups in Course I. First, the learning outcomes of the groups are presented, followed by the problems that affected learning outcomes of these groups.

3.1 Learning outcomes

The learning outcomes of the groups in Course I are presented in Table 1. The groups that were analysed were randomly selected. The numbers of the groups were those given in the course. The learning outcome, or score, is the number of points that the groups received for the FAST diagram that they produced. This score was determined with the use of an assessment protocol. Scores range from -7, to +7. In the next section, the problems that affected the learning outcomes are described.

Table 1 Learning outcomes of the groups in Course I

Course I – no intervention	
Group	**Score**
4	3
5	0
6	-2
7	4
10	1

3.2 Problem 1: Lack of understanding

The lecturer had developed the assignment for Course I to his best knowing. This means that the lecturer estimated that students were able to understand and apply the theory of the FAST assignment during the lecture with the use of instructions on paper. However, based on the observations, it appeared that all groups struggled with understanding the theoretical concepts of the assignment, and had difficulty applying these during the lecture. None of the groups achieved the maximum score. This demonstrates that the lecturer overestimated the students' capabilities to understand and apply the theory and instructions of the assignment. This has been recognized in literature as well and is known as the 'curse of knowledge.' This clearly became apparent during this research. Although the lecturer was aware of this phenomenon, the effect appeared greater than expected.

3.3 Problem 2: Instructions are not read

The results revealed that the two best scoring groups (7, 4) read and followed the provided instructions and examples more carefully than the groups that scored lower. These two groups applied instructions and used the examples provided in all steps of the assignment. In other words, they followed the assignment more strictly than the groups that scored lower (10, 5, 6). The average scoring group (10) applied instructions for step 1 and 2, but not for step 3. The two lowest scoring groups (5, 6) only used the examples provided, but in none of the steps did they apply additional instructions.

3.4 Problem 3: No strategy to handle assignment

The results have revealed that the average group (10) and high scoring groups (7, 4) not only read and followed the provided instructions and examples more carefully than the groups that scored lower, but they also explicitly discussed how to approach the assignment. In AT terms, they devised a strategy for tackling the assignment. The low scoring groups (5, 6) did not do that. They just started working without discussing a strategy in advance.

3.5 Problem 4: Skipping steps

The low scoring groups (5, 6) skipped step 1 of the assignment and jumped straight to step 2. This means that they started immediately with structuring the diagram, without brainstorming its elements first. It appeared that this way of working is less

effective, as these groups scored lower, needed more help from the lecturer, and needed to look at the results of other groups to be able to proceed.

4 DEVELOPING INTERVENTIONS FOR IMPROVING LEARNING OUTCOMES

In the previous section, several problems were described that affected learning outcomes of the groups. In this section, the interventions are described that were developed to solve the problems to improve learning outcomes. This is step 3 in the research.

4.1 Intervention 1: Separating explanation and application

As mentioned in the previous section, the interventions should address the theoretical principles of the assignment more explicitly because groups had trouble applying these. However, it may be ineffective to add this theory to the instructions and/or give students more time, as the results have shown that groups do not always read the instructions, or do not really understand them in the timeframe of a lecture (1.5 hours). A better option might therefore be to explain the theory in another lecture in advance of the application lecture. Thus, separating explanation and application. This provides the students with some digestion-time between the explanation lecture and the application lecture, and students can study the theory more thoroughly.

4.2 Intervention 2: Separating steps of the assignment more explicitly

The results have shown that some groups skipped step 1 of the assignment. This means that they started immediately with building a FAST diagram, without brainstorming its elements first. The results have shown that the quality of the FAST diagrams that these groups produce is lower than those of the groups that brainstorm functions first. To prevent jumping to step 2, it could be a good idea to separate the different steps of the assignment more explicitly. This can be done by separating and sequencing the instructions, in combination with timekeeping by the lecturer. By separating steps, the problem of skipping steps is solved, and the attention of the groups is more directed to each separate step.

4.3 Intervention 3: Stressing importance of instructions and strategy

The results have revealed that the high scoring groups read and followed the provided instructions and examples more carefully than the groups that scored lower. They also devised a strategy on how to approach each step. Therefore, at the start of the lecture, lecturers should explicitly stress that it is important to follow the instructions, and to think of a good strategy, before conducting each step of the assignment. Not only at the beginning of the lecture is this needed, but also later during the assignment this should be repeated. The lecturer will also write these instructions explicitly on a whiteboard and direct attention of the groups to the whiteboard during the assignment.

5 APPLYING THE INTERVENTIONS

The interventions were applied to groups in another course: Course II. Each group in Course II consisted of 5 to 6 students. Because there are multiple interventions, it

was also evaluated which interventions had the most effect. This was done by dividing the eight groups in two separate clusters of each four groups. The four groups in cluster A were subjected to a specific intervention (treatment group), while the other four groups in cluster B, were not be subjected to this intervention (control group). The results were compared.

The first intervention was to separate theory explanation from theory application in two different lectures with some days in between them. To test this intervention, it would be logical to subject the groups in one of the clusters to this intervention (treatment group) and the groups in the other cluster not (control group). However, to refuse half of the groups to follow the explanation lecture would be unethical and would probably lead to so much negative spin that the entire experiment would be disturbed. Therefore, all groups were subjected to the first intervention and hence they all followed the theory explanation lecture and the theory application lecture. Thus, with regard to this intervention, there was no difference between cluster A and B in Course II.

The other intervention was to stress at several moments during the application lecture that it is very important to read the instructions and examples carefully, and to devise a strategy. To test the effect of this intervention, it would be logical to subject the groups of one cluster to this intervention (treatment) and the groups in the other cluster not (control). However, that would require two different plenary starts for the two clusters, which would lead to practical problems. Therefore, also this intervention was applied to all groups in both clusters.

The final intervention is to separate the steps of the assignment more explicitly. This intervention was indeed tested in an experiment with a treatment and control group. It means that groups in cluster A received the instructions for each of the steps in the assignment in chunks and in sequence, while the groups in cluster B received all instructions at once and from the start. To carry out this experiment appropriately, the groups of cluster A were separated from those of Cluster B by a moveable wall, and students were not allowed to move beyond the wall. This experiment is ethically acceptable because all groups received the same information, only the sequence is different. Besides, students did not receive a grade for the assignment. Finally, this experiment can be conducted without students noticing it at first glance, because the assignments on the table look the same.

6 EVALUATING INTERVENTIONS

Regarding evaluating the effectiveness of the interventions, the first expectation was that the groups of Course II would score better than those of Course I because they were subjected to the interventions. However, the findings show that this was only partly the case. Four of the eight groups of Course II (groups 2, 3, 6 and 7) indeed scored equal to, or higher than the highest score in Course I (see Table 2). To clarify this, the highest score in Course I is 4 (group 7), but in Course II, four groups score 4

or even higher. This is in keeping with expectations. However, three of the eight groups of Course II (groups 1, 4 and 8) scored equally low, or even lower than the lowest score in Course I. The lowest score in Course I was -2, but the groups of Course II scored -2, -4 and -6. Thus, it cannot be concluded that the interventions have led to an increase in scores of all groups.

Table 2 Learning outcomes of the groups in Course I and II

Course I – no intervention		Course II – intervention			
No clustering		Cluster A		Cluster B	
Group	Score	Group	Score	Group	Score
4	3	2	5	1	-6
5	0	3	5	4	-2
6	-2	5	3	7	7
7	4	6	4	8	-4
10	1				

The second expectation was that cluster A groups would score better than cluster B groups, because cluster A groups received the assignments in parts (intervention 2). With regard to this expectation, the findings show that this is largely confirmed. As can be seen in Table 2, the four groups in cluster A scored much better than groups in cluster B. There is, however, one exception: group 7 in cluster B scores the maximum score possible, and higher than the highest score in cluster A. Nevertheless, based on these results, it seems likely that separating and sequencing instructions indeed improves learning outcomes.

7 EXPLAINING THE FINDINGS

The findings show that the groups in Course II score both higher and lower than those in Course I. Four of the eight groups of Course II score similar, or higher, than the best groups of Course I. This is in keeping with expectations and implies that the interventions have an effect. However, it was not expected that three of the eight groups of Course II scored considerably lower than those of Course I. An explanation why the scores of the three groups in Course II are so low, could be that these groups had a less effective group composition. For example, these groups could consist of weak students, or of students that could not work together well. This seems a plausible explanation, because literature has shown that the composition of groups can be of great importance for performance, not only in professional life, but also in higher education [9].

Another finding related to the effectiveness of the interventions is that in Course II, cluster A groups scored considerably higher than Cluster B groups. This means that, as expected, chunking the assignment seemed to have had an effect, as this was the only difference between cluster A and B. This is also in keeping with literature, in particular with the Cognitive Load Theory [10, 11]. Although not undisputed, this theory states, among others, that presenting material in a simple-to-complex, or part-whole sequence, reduces cognitive load and increases performance of groups [12]. This could explain the differences in scores between the groups in cluster A and B.

However, there is also contrasting evidence that does not support the idea that chucking and sequencing the assignment has an effect. Group 7 in cluster B has the highest score observed during this entire research, but this group has not received the instructions in parts and in sequence, but all at once. Based on expectations and Cognitive Load Theory, this group should not score so high. Most likely, group 7 is just a great group. A group that might have scored high under any circumstances. This also supports the idea that group composition is very important.

8 DISCUSSION AND CONCLUSION

There are some final remarks that need to be pointed out to put the research in the appropriate perspective. First, it appeared very difficult to draw valid conclusions with regard to the causal effects of the interventions. Not only because there is a limited data set, but also because there have been some unexpected results that require further study. Apart from the interventions applied, the results showed that there have been other factors that affected learning outcomes, but these are still unclear. Consequently, the interventions that were proposed in this research only increase the likelihood of improving learning outcomes, but do not guarantee it. Further research could study the effects of the interventions more in-depth. In keeping with our findings, it is particularly relevant to study the effect of group composition on learning outcomes. In addition, the effect of chucking and sequencing is worth further exploration. For this, the Cognitive Load Theory could provide helpful directions.

In this research, Activity Theory has been used as a framework to analyse the groups. This theory appeared to be useful as a structuring device to organize the data. However, the theory posits that tensions within or between the elements of group activity (represented by the Activity Theory triangle), can provide the leverage points for the group to learn, but in this research, it appeared that these tensions were difficult to detect. Let alone to observe how these tensions resulted in learning. Therefore, the idea to focus on these tensions had to be abandoned. Nevertheless, as an observation framework the Activity Theory triangle was very effective.

Finally, the goal of this research was to develop interventions to improve the learning outcomes of groups working on an engineering design-assignment during lectures. The idea was initially to limit the interventions to lecture interventions. However, the research showed that in order to improve learning outcomes, lecture interventions needed to be considered in a broader sense too, i.e. at the course level. As a result, the meaning of the word ‘intervention’ has changed during this research. It has extended to guidelines for embedding lecture assignments in the course as well. Nevertheless, this can be considered a good thing, because interventions in group work during lectures should not be isolated from the broader educational context in which they take place.

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AN INVESTIGATION OF THE RELATIONSHIP BETWEEN JUNIOR CYCLE SCIENCE STUDENTS' SPATIAL ABILITY AND SCIENTIFIC REASONING

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Keywords: *Spatial Ability, STEM, Second Level*

ABSTRACT

Research has shown that spatial ability is important for success in STEM. Spatial ability is closely linked with understanding often complex scientific concepts. It is important that the future STEM workforce, the current students in second level education, are developing their spatial ability and hence strengthening their STEM skills. This study presents an investigation of the relationship between spatial ability and scientific reasoning within Junior Cycle (1st-3rd year of second level) science students (12-15 years old). The tests used in this study are the Mental Rotation Test (MRT) [1] and the Lawson Classroom Test of Scientific Reasoning (CTSR) [2]. This study is part of a larger study currently in progress. Due to the current health crisis, the entire study could not be completed at this time. Data has been gathered for 84 students to date, with further testing scheduled for 100-200 students once restrictions are lifted. This paper presents preliminary findings to date. The analysis shows a significant correlation between Junior Cycle science students' spatial ability and scientific reasoning. There was no significant gender differences observed, however the percentage increase in spatial ability and scientific reasoning from first year to third year was higher for the boys. This study is relevant, as a better understanding of how to educate low spatial ability students, a group over-represented by females, in second level education could lead to the development of strong STEM skills and ultimately a higher uptake of the study of STEM by female students at second and third level.

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1 INTRODUCTION

There is a large gender imbalance within STEM disciplines and careers in Ireland today. In a report by Kavanagh et al [3], they estimated that only 25% of the STEM workforce is made up of women. There have been many research studies aimed at explaining and addressing this often observed gender gap within STEM fields [4-7]. It is a complex issue, where girls choose to not pursue their studies in STEM for many reasons. In order to be successful in effecting change, a multi-faceted approach would be ideal [3, 8]. Parents and teachers are one of the largest influences when it comes to girls choosing their subjects in school and third level education pursuits in Ireland [8].

However, there are also cognitive barriers to consider. Spatial ability has been strongly linked with success in STEM [4, 5, 9]. The link between scientific reasoning and spatial ability has been highlighted in various studies [10-12]. A particularly important finding from spatial ability research is the large and repeatable gender differences favouring males [6]. The largest gender differences are generally observed in tests of mental rotation, the particular spatial skill most associated with success in STEM [4, 13]. In this study, the aim is to investigate the levels of spatial ability, specifically, mental rotation ability, and scientific reasoning of a sample of Junior Cycle science students. If the relationship between these variables is better understood in this context, then this could lead to improvements in teaching practice, and help to aid the female students in particular to develop strong scientific and problem solving skills at this important time in their STEM learning. The research questions are:

- What is the relationship between Junior Cycle science students' skills in spatial ability and scientific reasoning?
- What are the gender differences, if any, of the Junior Cycle science students' spatial ability and scientific reasoning?

2 METHODOLOGY

For this study, Junior Cycle science students in one mixed school in Ireland were administered the MRT and CTSR tests within their normal science class (40 minutes duration). The MRT was given first, taking 7 minutes, and the CTSR given second, taking 30 minutes. 84 students were tested, with 32 students in first year, 18 students in second year, and 34 students in third year. 55 students were male, and 29 students were female. The age range was between 12-15 years old. All the students were taking the same level science class in Junior Cycle. All students had the opportunity to read and sign an informed consent form for the study. The researcher administered the tests in class, adhering to the recommended protocol and time limit for each subsequent test. The tests were presented as reasoning and problem solving tasks. The students were encouraged to answer each question honestly.

2.1 Instruments

For this study, two psychometric tests were employed. The Mental Rotation Test (MRT) [1] was chosen to measure spatial ability. This test is the redrawn Vandenburg & Kuse [14] mental rotation test. The MRT is a test of mental rotation ability specifically, a factor of spatial ability that has been shown to have large and repeatable gender differences [4, 6, 7, 13]. The MRT has 24 questions, with each question having four possible answers to choose from. For each question, two answers are correct, therefore 1 point is awarded only if the two options selected are both correct. The Junior Cycle science students' age is comparable to the US middle school student population (11-14 years old). The MRT has been shown to be suitable to use with this age group of students [15, 16]. In terms of test validity, Cronbach's alpha was found to be 0.87 [17].

For the scientific reasoning measure, the Lawson Classroom Test of Scientific Reasoning (CTSR) [2] has been chosen. The test aligns well with the learning outcomes of the Junior Cycle science curriculum, and is suitable for middle school age students. The CTSR has 24 questions, with each question having between three to five possible answers to choose from, with one correct answer per question. Questions 1-22 are paired, therefore one point is awarded only if both parts are answered correctly, i.e. questions 1 & 2, questions 3 & 4, and so on. Questions 23 and 24 are stand alone questions, with one correct answer per question. In terms of test validity, Cronbach's reliability was found to be 0.70 [18].

3 RESULTS

For this study, the variables were examined to investigate if gender differences existed for mental rotation ability and scientific reasoning. Table 1 shows the mean values in percentages of the variables, separated by gender.

Table 1: Comparisons of means for the MRT and CTSR by gender.

Test	Male			Female				
	n	Mean (%)	SD	n	Mean (%)	SD	t-test	Sig (2-tailed)
MRT	55	33.12	23.20	29	27.87	20.36	1.024	.309
CTSR	55	32.86	16.70	29	32.65	15.19	.064	.949

Table 1 shows the mean scores in percentage correct, averaged over all three years. An independent sample t-test was then performed, which showed there were no significant differences by gender for either measure. The sample is small and mixed in age range, therefore significant conclusions cannot be drawn at this stage of the study. Table 2 below shows the mean values of the variables, separated by year and gender.

Table 2: Comparisons of means for the MRT and CTSR by gender and year.

Test			Male				Female	
	Year	Mean Age	n	Mean (%)	SD	n	Mean (%)	SD
MRT	1	13	21	25.78	18.40	11	22.36	13.61
CTSR	1	13	21	27.86	17.23	11	30.79	14.18
MRT	2	14	12	33.34	27.52	6	45.13	33.89
CTSR	2	14	12	26.95	13.73	6	34.63	18.03
MRT	3	15	22	39.96	23.30	12	24.30	12.53
CTSR	3	15	22	40.92	14.86	12	33.36	15.84

Again, as the sample numbers are very small, no significant conclusions can be drawn. However, it is interesting to note that when the percentage increase in spatial ability and scientific reasoning is calculated from first year to third year, the boys percentage increase in spatial ability was 55.0%, compared to the girls at 8.7%. Similarly for scientific reasoning, the boys percentage increase was 46.9%, compared to the girls at 8.3%. Although the n is very small, this is an interesting preliminary finding. If this proves to hold as the sample increases, this could potentially indicate that, although the girls appear to have a similar level of skills as the boys in first year, they are not developing their spatial ability and scientific understanding as much as the boys do, as they progress through their science education. As this experience of Junior Cycle science is the basis for the students' subsequent choices of what subjects to pursue at leaving certificate level, this could mean that the girls are at a disadvantage when choosing to pursue STEM subjects further, and are perhaps more likely to avoid them. This is only speculative at this stage. Table 3 below, shows the correlational relationship between the variables.

Table 3: Correlation for MRT and CTSR

	n	CTSR	Sig. (2-tailed)
MRT	84	.502**	.000

The results show a moderate positive statistically significant correlation at the .01 percentile between mental rotation ability, and scientific reasoning. These preliminary findings suggest that there is a relationship between second level science students' spatial ability, and understanding of scientific concepts.

4 SUMMARY

The findings from this preliminary study showed no significant gender differences for spatial ability or scientific reasoning. However, the percentage increase from first year to third year in spatial ability and scientific reasoning was higher for boys, at 55.0% and 46.9% respectively, compared to the girls, at 8.7% and 8.3%. The correlational analysis showed a moderate positive relationship between spatial ability and scientific reasoning for Junior Cycle science students. This possibly indicates that a student's strength in reasoning spatially is related to their understanding of scientific concepts. However, as the sample is so small, no significant conclusions can be drawn from this study. As this paper is a work in progress, it will be interesting to analyse the data within the context of a larger sample as the study progresses.

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SCAFFOLDED STEPS TO DEVELOPING ENGINEERING STUDENTS' EPISTEMIC THINKING FROM PAPER-BASED EXERICISES TO OPEN-ENDED PROJECTS

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ABSTRACT

While professional engineers must frequently make compromises between competing outcomes and take decisions in the face of uncertain information, multiple studies have identified that most engineering students are ill-equipped to confront such situations. These skills fall into the category of sophisticated epistemic practices, an area of engineering students' training which is persistently underdeveloped.

The fine-grained approach of Elby & Hammer's relatively recent epistemic resources model takes a practical approach to observing the ways in which students interact and manipulate knowledge. This study exploys their approach to confirm the relevance and generalisability of Gainsburg's 2015 characterisation of the use of mathematical models in engineering. It uses an *a priori* analysis of the think-aloud problem solving behaviour of 8 engineering students in Switzerland.

An important outcome of this engineering-specific, fine-grained approach is that it can be implemented by teachers following Finster's recommendation that teachers design activities that challenge students to use n+1 strategies in order to promote the development of epistemic thinking. Consideration of the epistemic nature of these small strategies can assist teachers to create scaffolded steps for learners to acquire the sophisticated knowledge practices required to address real-world, complex problems both as students and graduates.

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1 INTRODUCTION

1.1 Why epistemic sophistication matters for engineering students

The increasingly complex and trans-disciplinary nature of professional engineering practice requires a well-developed understanding of the nature of knowledge[2]. The importance of epistemic sophistication for engineers is ubiquitous in the literature, in order that students "will be more capable of addressing engineering problem-solving in real world contexts because of their ability to see problems from multiple perspectives and recognize that more than one right answer exists" [1]. More prosaically, epistemic sophistication is present in the accreditation of engineering programs; for example 4 of the 11 student outcomes required by ABET explicitly include the complex context of environmental, social and ethical constraints [2]. The persistence of naïve conceptions in engineering graduates is clearly problematic. For example, a graduate with an unexamined trust in figures of authority and a belief in the existence of a single correct answer to real world applied engineering problems is ill-suited to exercise the judgement required of a certified engineer. It is thus disconcerting to note that Pavelich & Moore [3] and Wise *et al.* [1] found only a quarter of engineering students who completed their undergraduate degrees held sufficiently sophisticated epistemic beliefs to choose appropriately between competing knowledge claims in a complex environment.

Although the study of epistemic beliefs has attracted significant research effort since its inception in 1970 by William Perry, a model that permits robust quantitative measurement has proved elusive. This study takes a pragmatic approach to epistemic beliefs by focusing on students' epistemic practices [4], which are the sense-making and knowledge justification strategies, employed during problem solving. This characterisation of engineering students' more and less sophisticated epistemic practices is desirable as it can serve to assess students' ability to confidently navigate in complex, open-ended engineering environments.

1.2 A succinct literature review

There is near-unanimous agreement that naïve epistemic beliefs take a dualist, absolutist view of knowledge, while a more sophisticated epistemic approach involves an awareness of the constructed and evolving nature of knowledge and the development of criteria against which to evaluate knowledge claims. However neither the early stage-based models nor the semi-independent dimensions models have an adequate empirical foundation [see 4]. The long-running debate about the generalisability of epistemic beliefs has been decided in favour of domain-specificity. However, taking "science" as a discipline is clearly too broad, as illustrated by Tsai's study showing differences in students' epistemic conceptions in physics and biology [5].

[2] This area was historically referred to as 'personal epistemology' but is now plagued with a chaotic mess of terminology. Please see [4].

Elby and Hammer's cognitive resource model [6-7] marks a significant departure from previous models by taking a highly contextualised, fine-grained approach to characterising the different ways that students interact with knowledge. Their model seeks to address two major shortfalls of previous models; (1) instruments that are too general and coarse-grained, and (2) a failure to differentiate between the correctness and productivity of different epistemic practices. Elby and Hammer's model posits that people have a set of cognitive resources from which they chose which element to bring to bear in each specific context. The naïve approach will be the most effective, and thus appropriate, in some situations despite the range of strategies available to the student. In fact, rapidly alternating between high and low epistemic approaches resembles the problem solving of expert engineers, as the applied nature of engineering involves repeated navigation between abstract models and physical reality. For Elby and Hammer, effective epistemic cognition is adopting an appropriate knowledge practice for a specific knowledge claim. Thus, higher epistemic sophistication is not identified by the consistent use of high-level behaviours but rather an ability to select and employ productive cognitive resources.

Gainsburg's 2015 study [8] investigated, in the fine-grained manner of Elby and Hammer, the problem solving behaviours of 9 American civil engineering students' while working on their homework assignments. She identified various behaviours representative of the use of mathematical models in engineering problem solving and then organised them into a 4-level framework of increasing epistemic sophistication.

The current study has 2 aims. First, to test the relevance of Gainsburg's model in a novel culture (Switzerland) and across multiple study programs, and secondly, to leverage these observations to examine how the learning tasks can be structured to better support students' epistemic development.

2 METHODOLOGY

2.1 Think-aloud problem solving protocols

Think-aloud protocols were used to provide information about the strategies and approaches used by students during problem solving. While this method requires students to verbalize their thought processes, a task constrained both by cognitive load limits and the self-awareness of the student, it makes the connection between epistemic conceptions and actions visible. The think-aloud problem solving protocol was immediately followed by a stimulated recall interview which focused on elements relevant to epistemic beliefs. Each student's own written work was used to structure and anchor the interview.

2.2 Problem solving tasks to elicit epistemic practices

A series of 4 tasks were designed to require a diverse set of problem solving strategies without requiring knowledge beyond that of a typical first year engineering curriculum. While the think-aloud tasks were intentionally constructed to avoid providing any formulae or equations, the problem statements were designed to

prompt students to remember and use fundamental equations from physics and thermodynamics. Each task was presented in a contextualised format to offer opportunities for students to verify the plausibility of answers or to employ real life observations. An example was the possibility to use whether a 10 degree temperature change would be acceptable for an *in situ* dental polymerization as advance problem solving.

2.3 Analysis Using Gainsburg's Model as a Framework

Gainsburg's descriptions of epistemic practices [8: p.156] were culled to those relevant to an isolated think-aloud problem solving task. This meant eliminating behaviours which would not occur outside the context of a course, such as "Sees no connections among course content (unless topics are identical)." The behaviours retained are presented in *Table 1* and were used as *a priori* codes to mark specific episodes in the transcripts across both the problem solving and stimulated recall portions of the interviews. This short study does not make a distinction between enacted behaviours, such as a student previewing her method for how to go about solving the problem, and professed beliefs, such as recounting her habit of discussing different problem solving approaches with other students. Sessions with students lasted between 60 and 90 minutes, largely depending on students' facility and determination in solving the exercises. In total, the data comprised 79 coded episodes, with 8 to 14 episodes per student.

Table 1. Selected Codes for Engineering Students' Enacted Epistemic Views [8]

Stage 1 – Dualism	**Stage 2 – Integrating**	**Stage 3 – Relativism**	**Stage 4 – Sceptical reverence**
Believes engineering can be done as a purely mathematical enterprise	Will step back and look at the overall picture	Seeks deep understanding even if it delays solving the current problem	Big picture present throughout problem solving
Goal for exercises is to get the right answer	Goal for exercises is to train the mind	Verify solution using own experiences	
Answer key or instructor sole means of verifying solution	Uses units on intermediate values to guide solving process	Attempts to relate values to physical phenomena, to guide solving	Assess reasonableness of answers, computer output
No effort to connect mathematical procedures to real-world phenomena	Sense-making using concepts, math	Sense-making using real world observations	Recognises fallibility of models, need to understand underlying assumptions
Little trust that peers have useful ideas about problem solutions	Discusses with peer to refine understanding	Discusses with peer to learn from peers' ideas about	Recognises non-routine nature of solving problems and the need for judgement

		solving methods, even if imperfect	
Pattern-matches to previous problems, without understanding	Uses methods other than those of instructor	Previews task and states overall plan and predicts result	

2.4 Participants

Following approval from the institutional human research ethics committee, eight students from a range of different study programs were recruited. Purposeful sampling was employed to obtain diversity in the year of study and study program, as presented in *Table 2*. Students are identified by a pseudonym of their own choosing, where a name beginning with A indicates a first year student and a first letter C name is a third year student.

Table 2. Study participants

Pseudo	Year	Study Program
Amandine	First	Computer engineering
Anna	First	Electrical engineering
Antoine	First	Life Science engineering
Benoît	Second	Microengineering
Boris	Second	Mechanical engineering
Clément	Third	Microengineering
Damien	Master1	Technology Entrepreneurship (B.Eng electrical)
Ernest	Master2	Environmental engineering (B.Eng civil)

3 RESULTS

3.1 Epistemic behaviours exhibited by students during problem solving

Applying the behaviours described by Gainsburg, listed in *Table 1*, as *a priori* codes allowed the frequency of behaviours at each level to be recorded. It is important to note that the observed behaviours are diverse in nature, ranging from a single instance constructing a table of values, *as he always does with this kind of exercise,* despite not being sure what is asked (level 1) to reporting that the solutions provided by the instructor would be the only way to check a calculated answer (level 1). Further, the number of codes per level is not consistent. It is thus simplistic to report the level which occurs most frequently as though each behaviour is of equal importance, but it does provide a crude measure of the range and distribution of students' various epistemic practices.

Despite the relatively brief format of the sessions, each student was observed to use a range of different approaches, as shown in *Table 3*. All students exhibited at least one example of level 1 behaviour and at least one example of level 3 behaviour,with

the exception of Benoît. Benoît did not exhibit any level 1 behaviour and was unique to demonstrate awareness of the limitations of the models underlying the equations employed during the problem solving (level 4).The most common level 1 behaviours were making no attempt to relate mathematical procedures to real-world phenomena and seeing the goal of exercises as getting the right answer. Using concepts and maths to make sense of the tasks, illustrated by Anna's quote below, were by far the most common level 2 behaviours. Sense-making using real world observations was the most common level 3 behaviour, illustrated by Ernest's quote below.

> *« When air condenses to solid on the windshield... logically, when it freezes it would lose energy, right? Yeah, because it changes state. The vibrational state is lower. »* *Anna*
>
> *"I was thinking more like on the street, like I'm walking in the winter. It's winter, therefore it is cold. I just don't picture myself taking energy from another object. It's just me losing the energy."* *Ernest*
>
> *"Given that chemists invented the mole, which is very practical, it not surprising that they use it in concentration. This is not an equation where I have a lot of doubt. However, there is more ambiguity in the equation I used a minute ago, PV=nRT. There are a lot more hypotheses behind it. Here you can't be in just any conditions, it is more complicated, there are approximations."* *Benoît*

Table 3. Frequency of Behaviours Exhibited by Students in Think-aloud & Interview

Name	1 – Dualism	2 – Integrating	3 – Relativism	4 – Sceptical reverence
Amandine	2	4	2	
Anna	1	6	4	
Antoine	2	5	1	
Benoît		7	3	1
Boris	4	5	1	
Clément	5	6	3	
Damien	2	5	1	
Ernest	2	6	1	

All students were observed to use level 2 most frequently, despite all students exhibiting higher level behaviour on at least one occasion. This broad range and below-peak functioning is consistent with Gainsburg's study. A notable difference is that she found level 1 to be most commonly exhibited by students, but her participants were working on their own course work and had access to their notes. The tasks constructed for this study were intentionally unfamiliar to students and no study resources were provided, which makes many level 1 behaviours such as

pattern-matching less accessible. These differences are particularly salient given the context-dependant nature of the epistemic resource model employed in the study and serves to reinforce the findings. The differences between the observations of the two studies are interesting for what they reveal about how tasks can be designed to encourage students to use more sophisticated epistemic practices.

3.2 Implications for epistemic beliefs models in engineering

This study tested the generalisability of Gainsburg's model of epistemic beliefs [8] in engineering by asking students from several different study programs to solve think-aloud chemistry tasks with real world contextualisation. While some of the behaviours identified by Gainsburg were not observable in the experimental conditions of this study, most of the behaviours related to different problem solving approaches in levels 1, 2 and 3 were observed in this small study. As with Gainsburg's own study, level 4 behaviours were rarely observed. Thus, the observations of this study supports the relevance of Gainsburg's model across engineering disciplines and to non-Anglophone educational systems. Future work will include a grounded theory approach to the themes arising from the think-aloud data.

Observations in this study also support the epistemic resources model of Elby and Hammer [6-7], where individuals draw on the different resources available to them depending on what will be effective in the current context. Students were observed to employ a broad range of behaviours on the different tasks and at different moments during the tasks. Students were observed to function at level 2 most frequently, as this appeared to be most effective for the tasks at hand. This is consistent with Elby and Hammer's definition of epistemic sophistication as the ability to select and employ productive cognitive resources.

3.3 Recommendations for teachering engineering

Worryingly, students reported that the tasks and assignments which constitute the bulk of their university experience do not encourage them to adopt more sophisticated epistemic practices. Demonstrations of problem-solving and assigned exercises appear to nearly exclusively feature single, precise answer tasks that preclude the need to check the assumptions of the models used or tolerate uncertainty. The ability to calculate a highly precise answer was generally taken by students as equivalent to a highly accurate answer, completely ignoring any simplifications or approximations employed in obtaining the equation used to model the system. Further, it seems that assigned tasks rarely provide sufficient contextualisation for students to leverage their lived experiences for sense-making or answer checking, and do not require students to make estimates or work with imprecise values. These observations may contribute to why engineering students develop more slowly in their epistemic practices than other students [10].

In order to assist students in adopting more epistemically sophisticated practices, Finster [11] recommends that teachers create opportunites for students to employ n+1 strategies. The detailed, engineering-specific practices outlined in Table 1 can

serve as a guide for teachers to create appropriate n+1 activities that stimulate epistemic growth. Providing opportunities for students to work in less constrained, more imprecise situations, will better equip students to work on big, open-ended projects at school and in their future professional lives [1].

4 SUMMARY AND ACKNOWLEDGMENTS

This small study supports the 4 level framework of engineering-specific epistemic practices proposed by Gainsburg [8] and its generalisability to other areas of engineering. Additionally, the diversity and sub-peak behaviour functioning are coherent with the cognitive resource model of Elby and Hammer [6-7].

While Marra et al. [9] found that epistemic beliefs do change over 4 years of engineering undergraduate studies, Paulsen and Wells [10] found that, when controlling for other demographic factors, engineering students were more likely to hold beliefs about knowledge being simple and certain than other fields. This researcher hopes that the fine-grained characterisation of more and less sophisticated epistemic practices in engineering will make it more accessible for instructors to obtain insight into this aspect of engineering students' thinking and thus make targeting the development of such abilities a more explicit goal of their teaching.

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REMOTE LABORATORIES IN ENGINEERING EDUCATION. DERIVING GUIDELINES FOR THEIR IMPLEMENTATION AND OPERATION

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ABSTRACT

Exploratory laboratories are fundamental to engineering education, since they enable students to apply theoretical subjects to practical situations. The ongoing technical innovations are rendering remote laboratories possible. However, their implementation and operation encounter several challenges. This contribution gives an overview about the experiences gained throughout the project ELLI over a time period of 8 years. In 2012, a whole variety of remote laboratories was set up. At Ruhr-University Bochum, they are associated with Civil and Environmental Engineering, Mechanical Engineering, and Electrical Engineering and Information Technology. At TU Dortmund University, they are related to manufacturing processes, especially forming technology. To avoid individual software solutions, LabVIEW was set as standard tool throughout all applications. To summarize the experiences made, a final evaluation study was conducted in 2018 and 2019. The research design of this evaluation comprised a non-standardized survey method: From October 2018 to September 2019, a total of 11 expert interviews was under-taken with research assistants and professors. The interviews followed a semi-structured guideline which had previously been developed in a focus group discussion, containing five categories of leading questions. The transcribed interviews were analyzed via qualitative content analysis. This contribution presents challenges as well as potential for the use of remote laboratories in engineering education, in order to make the experiences gained available to the scientific community and to encourage further exchange about the use of digital innovations.

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1 INTRODUCTION & BACKGROUND

The current trend of remote experimentation provides new possibilities to enhance engineering education. Right now, different types of remote experiments, virtual and physical, are available. Hence in this publication, the term remote laboratory defines laboratories once there is a remotely operated experimental setup involved. Remote experimentation is used in several different disciplines with the main usage in electrical and control engineering [1,2], where downsized model plants are often used [3]. In this publication, laboratories in the field of mechanical engineering are dealt with. To provide a remote experiment, remotely controlled machinery, infrastructure to connect the laboratory to a public network, management systems for user scheduling, as well as experimental data transfer and storage, are needed.

The investigated remote laboratory in this study is developed as a part of the German project ELLI. This project is a collaborative effort at the RWTH Aachen University, TU Dortmund and Ruhr-University Bochum to improve the available methods for engineering education. In continuation of the results published in [4], which are based on the results from the remote laboratories at the Ruhr-University Bochum (RUB) alone, this research is focused on the remote laboratory at the TU Dortmund (TUD). At RUB, several laboratories were developed by different institutes and chairs of the engineering faculties, whereas the laboratory at TUD represents a more extensive and interconnected laboratory developed by the Institute for Forming Technology and Lightweight Components (IUL). The following paragraph gives a short description of the development team and the laboratory. More specific details can be found in [5]. The main components are depicted in Fig 1.

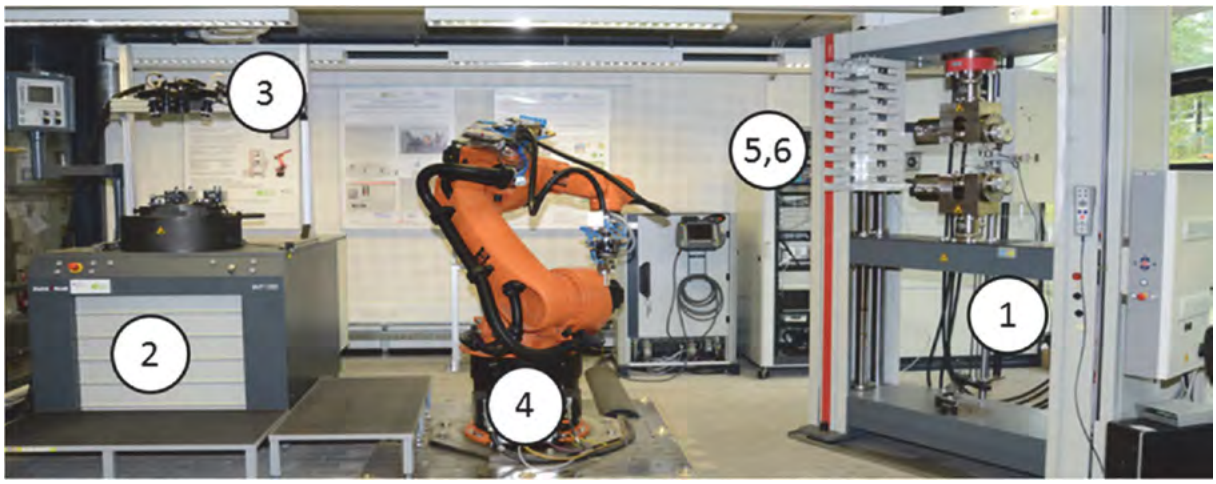

Fig 1. Fully automated tele-operative testing cell for material characterization as in [5]

The remote laboratory allows for the conduction of different experiments, featuring a tensile test stand (1), and a cupping test stand (2), both of which are fundamental for material characterization in mechanical engineering. The machines, robots (4), and microcontrollers (5) are connected by an overlaying control and safety system (6), which is based on the software LabVIEW, and an optical measuring system (3). Nowadays, access to the remote lab is provided by a self-developed control and user management platform. The development team was and still is a multi-disciplinary one comprising manufacturing engineers, mechanical engineers as well as automation and IT specialists. This paper deals with the development of the laboratory during the last 8 years, the lessons learned and compares them to results derived from the study

conducted at RUB. Thus, 8 years of experiences of two collaborating universities are shared, covering different kind of remote laboratories. The results are combined to extend existing guidelines for lecturers wanting to develop new remote laboratories from the ground up or based on their existing machines.

2 RESEARCH DESIGN OF THE LABORATORY EVALUATION

A qualitative study with expert interviews was conducted as described in [4]. In summary, the interviewees were questioned "based on their role as an expert for a certain field of action" [6], concerning 5 different topics. These topics are listed in Table 2. A semi-structured guideline with open questions was used for the interview that covered all stages from the initial planning phase to the permanent implementation in education. Follow-up questions were asked whenever the interviewer felt that certain aspects remained unmentioned or if certain answers needed elaboration. The interviews were recorded via a voice recorder, transcribed, and analyzed by qualitative content analysis [7]. Therein, information was categorized according to analytical categories defined before the beginning of the investigation and subsets for each analytical category were formed. All the while, the analysis remained open to the dynamic formation of new categories or restructuring of subsets. The final categories and subsets were compared to the aspects found in [4], adding one further category.

Table 1. Categories of interview guidelines

Topic 1	General questions and history of the remote laboratory
Topic 2	Planning phase of the laboratory
Topic 3	Development and implementation
Topic 4	Conducting experiments
Topic 5	Conclusions and outlook

3 RESEARCH RESULTS / LESSONS LEARNED

The results were categorized using the aspects found in the study at RUB: technical and technological challenges, didactic concepts and learning objectives, and project management. An additional category dealing with the long-term implementation of the remote laboratory was added. First, the findings at TUD are presented and then compared to the study conducted at RUB. This gives insight into similarities and differences of the development of several smaller remote laboratories compared to the development of a single larger laboratory.

3.1 Technical and technological challenges

In this section, the findings and experiences regarding the implemented technology are presented. The main technical elements mentioned in the interview were automation and control of both hardware, which includes machinery, cameras as well as control units, and software components, graphical representation of the laboratory, and safety measures to protect hardware and personnel.

Findings at TUD: The physical components were chosen from commercially available hardware. This focused the development on the required software and controls, which in its current properties contains several years of development. For control and automation of the equipment, the trial-and-error method sometimes had to be used to

achieve compatibility between hardware and software even though the installed communication protocols were known, leading to highly complex systems. Due to the complexity of the systems, a self-developed platform was created. It functions as a user management and scheduling system and allows for the control of any number of experiments allowing the team to work on both systems separately. It also redirects validated users to other webpages, being the graphical user interface (GUI) for the remote laboratory. Executable commands are integrated by buttons and input fields enabling the choice of values for the experiments.
The integrated safety measures prevent damage to personnel as well as to the equipment. A hardware-oriented system, which is disconnected from the remote-controlled system, functions as an emergency shutdown if detecting movement near the equipment. It requires a manual restart after each emergency shutdown. The software-based safety measures restrict experimental parameters to safe limits of the machinery and predefined movement of the robots, preventing misuse of faulty use. Operation is only possible when both systems are active and no error is present. Additionally, the systems only allow the transition between safe states of operation informing the user about invalid actions and denying their execution.

Comparing both universities: It became apparent that the complexity of the remote laboratories was a challenging factor. Therein, it was distinguished between the complexity of the user interface and the complexity of the underlying control system. To create a stable system, certain limitations and simplifications had to be made at both universities. This became especially apparent for some laboratories at RUB, where experiments had to be significantly altered from the way they were conducted as hands-on experiments. The laboratory at TUD was chosen for easier “remotization”, i. e. transition into remote operability. It already was highly automated, thereby lost almost no sensory feedback, and needed less alteration in general. At RUB, the aim was to conduct "usual experiments" as remote experiments, while at TUD, a highly automated experimental setup was chosen for degree of realism and increased learning potential. At RUB, most laboratories relied on some level of abstraction, while at TUD, an interface design was chosen to approximate the students being in the laboratory as realistic as possible, incorporating video streams and experimental raw data. In all cases, the learning objectives and target audience played a huge role in the design of the user interfaces. Finally, during the study at RUB, most interviewees stated that nowadays they would also recommend integrating more sensory feedback into the interfaces. At both universities, the implemented safety measures were implemented on the hardware as well as on the software side of the labs. For all labs, they imposed limitations and restrictions on the experimental setup. However, maintenance efforts were decreased simultaneously, ensuring long-term operation of the labs. The long-term operability of the system was in all cases established by a reduction of selectable process parameters. The safety measures also include means for an emergency shutdown via the user interface or through the hardware at any time during the experiment. After every emergency shutdown, a manual reset is required to guarantee the analysis of the shutdown, and to prevent the same error in the future.

3.2 Didactical concept and learning objectives

The didactical elements presented in this section are considering the inclusion of students' perspective, collaboration with experts in didactics, graphical representation

needed for education, students' preparation for the experiments as well as the utilization of the remote experiment as a teaching tool.

Findings at TUD: The targeted audience is Bachelor's students of mechanical engineering, mechanical engineering informatics, industrial engineering, and logistics. The students' perspective was considered through the team's reflection and experiences, as most of the team took the same course of study. Still, it was recommended to acquire the opinion of students for the final touch of the development. From the beginning, a didactical team supported the technical team by advising the selection of experiments, discussing learning objectives, improving the utilization of the remote laboratory, and by continuously evaluating the learning outcomes. The principal learning objective was determined to having the students learn how to use this remote laboratory to answer scientific questions instead of learning how to operate the equipment. A setup was chosen for which the limitations due to the safety measures only slightly differ from the hands-on version. This enhances the focus on the learning objectives as only actions aligning with the learning objectives are allowed. Additionally, the control of the GUI was designed as faithful as possible to the hands-on experiment to create a realistic impression of "being in the lab. Each student is granted a limited time slot, therefore groups need to combine relevant data and have to apply project management skills. Required background knowledge from lectures is examined in a digital quiz before the start of the experiment. Finally, before the conduction of experiments, an introduction into the control and user management platform and the GUI is available by presentation and video tutorials.

Comparing both universities: The initial target audience for the remote laboratory at TUD was students in the Bachelor's program only, while the initial target audience at RUB also included students in the Master's program. However, for testing purposes the remote laboratory at TUD was first used in the international Master’s pre-course due to smaller group sizes. The students' perspective was rarely asked for in the design of the GUIs, as most teams consisted of (former) students or student assistants. Yet in this study, it was recommended to integrate the students’ perspective during the final development of the user interface, thereby preventing uncertainties in explanations about control and concepts. A difference was found considering the cooperation with didactic experts for higher or engineering education. At RUB, the members of the engineering faculties rated their expertise in teaching as sufficient and stated that the required understanding of highly complex measurement techniques was most important in deriving appropriate teaching approaches. On the other hand, the team at TUD continuously cooperated with a team of didactic experts in the development of the laboratory. Concerning the required levels of automation and usability, those were similarly high at both universities. This potentially enabled users to conduct experiments without understanding the involved mechanisms. Due to this, the original learning objectives had to be adjusted and the focus was shifted from understanding and executing of a measurement technique to the gathering of experimental data and the subsequent evaluation. At TUD, those learning objectives were already defined at the beginning with the didactical teams’ support. As a final point, some of the developers at RUB expressed it to be unlikely that a remote experiment can fully replace a hands-on experiment. Mentioned reasons regarded the importance of the more comprehensive, yet mostly unnoticeable, safety measures, absent development of manual skills, and faulty perception of time. The team at TUD

also regards their laboratory as valid and comprehensive substitute, that is yet best used in combination with additional hands-on experimentation.

3.3 Project management

Lessons learned regarding project management, i. e. dealing with teamwork and knowledge management, time management and unforeseen delays are summarized.

Findings at TUD: During the development phases, the teamwork changed from more individual work to shared work. Regular team meetings were used to discuss recent and pending developments. This has proven to be useful in times when research assistants were leaving or joining the team due to their expiring contracts. Additionally, some team members have worked on the project almost from the beginning. This shared knowledge allowed to only document successful ideas, and to omit ideas that had proven to be unfeasible due to too high effort.
Time management was often impaired by external factors, which sometimes necessitated the reduction of self-imposed aims to keep the development on time. Adjustments to the safety measures have proven to be especially time-consuming. According to the interviewees, a full work-year has been needed until the laboratory was able to be used, and then only in its most fundamental functionalities. Concerning overall project management, the effort proportionality for each new development idea had to be carefully evaluated. Alterations to initial concepts were only feasible if they enabled a reduced effort for a high number of cases. On the other hand, student theses being related to the development of specific aspects of the remote laboratory were a welcome addition.

Comparing both universities: For all laboratories, the initial schedule experienced delays because of unforeseen challenges. The requirements for the development of hardware or software solutions were often underestimated by the research staff and lead to significant delays for most projects. For some of the more complex laboratories at RUB, the learning contents, as well as the hardware, had to be downsized and adjusted multiple times during the development. The choice of a technical and didactical suitable laboratory at TUD rendered these iterations unnecessary. The setup of a remote laboratory demands interdisciplinary skills working together, from the respective field of engineering in which the laboratory is used, electrical and control engineering, and automation as well as programming. The interviewees often mentioned that additional expertise therefore had to be acquired. During the interviews at RUB, it was recommended that at least one person should oversee the project and work on it during its entire development time gaining knowledge in the required fields and additionally serving as a form of documentation. The developments at TUD serve as an opposite example, since the mixed team of mechanical engineers, programmers, automation engineers, and electrical engineers reported no such problems. This allowed for easier setup of the experiments and a stricter focus on the control system and didactical aspects. For all laboratories, the interviewees mentioned that standard procedures for documentation are not suitable and need to be adjusted. In this study, the interviewees stated that developments and new possibilities were discussed in the whole team and only successful developments were documented. As a final aspect, the team at TUD had at least one team member working on the project for the entire time. This helped accumulate and store knowledge about the project, and it positively influenced the documentation.

3.4 Long-term implementation

This fourth and final paragraph contains lessons learned about the transition to a permanently operated and maintained remote laboratory as well as other beneficial aspects regarding the development and synergistic effects.

At TUD, the fully developed remote lab, initially demanding huge effort, significantly reduces staff's workload and operational costs by dispensing with the need for safety and operating instructions and the provision of personal protective equipment for every participant. Due to its limitations relating to safety measures and the learning objectives, the remote laboratory is unfit for conducting scientific research. Yet, the equipment is extensively used for scientific research and student research projects in its hands-on version, requiring only slight modifications. This generates synergistic effects or a "second use-case". This „second use-case" contributes to the preservation of the remote laboratory beyond its funding phase since the equipment still generates scientific value in their standard, non-remote operation mode. Therefore, arrangements between educators and researches have to be made regarding the scheduling of remote experimentation and scientific research. Hence, the remote laboratory configuration has to be restored after each research period. In the interviewees' opinion, applying for research funding should become more likely to succeed in combination with educational context as a second-use case for expensive machines. Developing a remote lab with already available equipment should focus on such equipment that is scientifically used with sufficient downtime for educational purposes and control units that are easily configured for remote control.

4 CONCLUSION: RECOMMENDATIONS FROM LESSONS-LEARNED

The qualitative study via expert interviews has proven to be a suitable method for this evaluation as it allowed for responsive questions, which lead to the fourth category not explicitly mentioned in the previously conducted study. The conclusions drawn from this study and the comparison to the previously conducted study are given in the form of recommendations for others interested in the task of developing remote laboratories.

As technology advances and software solutions regarding connectivity and remote control has become more and more available features in recent years, the effort of developing new laboratories is significantly reduced. Still, the required complexity of the remote laboratory should be discussed and its effort-to-use ratio should be evaluated carefully. This transition might necessitate an adjustment of learning objectives. In the following, guidelines regarding encountered technical challenges are given:

- For "remotizing" a lab with new or already existing equipment, use hardware that already features remote operability, Alternatively, begin with available open source software packages to connect existing machinery via well-defined interfaces. In both cases, direct support from the manufacturers is recommended.
- Separate laboratory control from user management, e. g. by utilizing a central content management platform. This provides the benefit of being able to work on both systems in parallel and to integrate further laboratories via the same interfaces.

- Integrate safety precautions both on the software- and on the hardware-side. Restrict the selection of parameters to ensure the equipment, and to provide staff's safety. In addition, enable an automated shutdown in case of faulty operational states or parameters.
- Use the safety measures to enhance the focus on learning objectives, by denying executions of faulty decisions and giving appropriate explanations.
- Incorporate adequate sensory feedback (i. e. video- and audiostreams or animated process visualizations) to give a realistic impression of "being in the lab". Use those to sharpen the focus on the learning objectives, e. g. process visualization, control algorithms, or analysis of experimental data.

In remote laboratories, no direct feedback from supervising instructors is available, therefore the didactical approach has to be appropriately well-defined. Recommendations regarding the didactical concepts are listed in the following:

- Cooperate with experts in didactics to evaluate your laboratories' potential for "remotization". Already highly automated setups are preferable.
- Define targeted audiences and create learning objectives for each one. Incorporate those into the user interfaces, only depicting necessary features. Start this process already before starting the technical development.
- Provide instructions for the handling of remote systems, especially for experiments that can be repeated a limited number of times only.
- Integrate feedback from the targeted audience into the final designs of user interfaces and the systems' instructions. Evaluate the system with a limited testing group first.
- Consider the remote laboratory as a tool to enable further didactic methods and see it as an extension rather than a replacement to traditional laboratory work.

The development of a remote laboratory can be a time consuming task requiring high effort. Therefore, several aspects regarding project management are recommended:

- Appoint one or more persons in charge for the whole period of the expected development time, especially when team member exchanges are common practice like in German higher education.
- Assemble an interdisciplinary team, consisting of programmers, electrical, control and automation engineers.
- Discuss and document recent and current developments in regular intervals, to facilitate knowledge management throughout the project.
- As time management has proven to be very challenging, define a multi-layer approach and start by implementing base functionalities of the laboratory, which can be improved later. Also, a generous scheduling of the project is recommended.
- (Optional) Concerning necessary approvals of changes of infrastructure or safety measures in your laboratory, retain flexibility by specifying what you want to achieve. Still, remain as unspecific as possible regarding the chosen methods, as unforeseen changes might later become necessary.

The transition of the developed remote laboratory into permanent operation at the chair needs to be rated as beneficial, despite the necessary maintenance effort. To achieve this aim, the following recommendation are given:

- Remote laboratories should reduce workload and operational cost by not requiring supervision or safety instructions for students. Carefully consider the costs of a full automation against having to take manual action from time to time.
- Increase the nominal operating hours by also conducting scientific research in the laboratory, probably in a slightly less restrictive mode of operation.

Finally, partial developments of remote laboratories can be used for student theses, giving students the chance to work on a real project and acquiring additional skills in an interdisciplinary field. All in all, remote laboratories can be greatly beneficial to students' education and, despite the initially high effort, reduce costs and workload of the staff in the long-term.

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VIRTUAL REALITY TRAINING OF PRESENTATION SKILLS: HOW REAL DOES IT FEEL? A MIXED-METHOD STUDY.

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Conference Key Areas: *E-learning, open and online learning, blended learning, virtual reality*
Keywords: *Presentation skills training, Virtual Reality, Immersion, Personality*

ABSTRACT

Being able to deliver effective and compelling presentations to various audiences, becomes more and more important for engineers. However, with full curricula and growing numbers of students in engineering domains, the training of good presentation skills often receives (too) little attention. Instructors don't have time to train the students intensively, let alone that there is room for individual, formative feedback. The use of Virtual Reality (VR) might offer a solution. With this technology, students can practice their presentation skills on their own in front of a virtual audience.

The study presented here is part of a line of research into the effects and user experiences of VR presentation skills training for students of engineering. The current study is about capturing the user experience and focused on an attribute that is assumed to be central to VR technology, namely the capacity to induce a strong sense of immersion in the user. The current study sought to explore if VR users respond to a virtual audience as were it a real audience. In order to investigate this, a mixed-method study with 46 students from a technical university was applied, in which the responses from the virtual audience were manipulated, and the effects of those manipulations on the level of user immersion were measured. We also investigated if personality traits moderated these effects. Quantitative (questionnaires) and qualitative (interview) data were collected to capture the effects of the manipulation, and the extent to which personality influenced the responses of users to the VR experience.

1 INTRODUCTION

1.1 Problem statement

More than ever before, engineers have to deal with complex technical problems in interdisciplinary teams and in competitive market conditions. About 60 percent of the work of engineers is communicating with others [1; 2]. Therefore, it is of utmost importance that engineers are capable of communicating clearly and are able deliver effective and compelling presentations to various audiences, including colleagues,

management, and clients. Companies actively search for engineers who have these skills [3].

Engineering studies recognize the importance of these communication skills. However, with full curricula and growing numbers of students in engineering domains, the training of good presentation skills often receives little attention. Instructors don't have time to train the students intensively, let alone that there is room for individual, formative feedback. The use of Virtual Reality (VR) might offer a solution. With this technology, students can practice their presentation skills on their own in front of a virtual audience.

1.2 Training of presentation skills

In the literature about 21st century skills, it is often emphasized how important it is that students can train complex skills in realistic contexts [4; 5]. In the case of presentation skills, this means that students must be able to train their skills in front of an audience. The realism of the practice context in presentation skills training is important for two reasons. First, most people experience some level of stress will speaking in public. In some publications it is estimated that at least 75 percent of the student population fears speaking public [6]. The stress affects their posture, gesturing, use of voice (e.g., speed, pitch), and so on. Students have to get used to such stress and learn how to deal with it. Second, during a real presentation there might be interfering factors, such as mobile phones that are ringing, people in the audience that appear distracted or uninterested. Students must also learn how to deal with such situations, or at least how they can keep their focus on their presentation, without getting distracted.

In the previous section, the use of VR was suggested as a solution that could offer students a venue where they can train their presentation skills in front of a (virtual) audience. The question is however: does such a virtual environment really make students feel like they are in an official lecture-hall giving their presentation in front of an audience? And if so, could this virtual experience, or perhaps we should call it 'perceptual illusion', be so compelling, that students even respond to the non-verbal behavior of the virtual audience?

1.3 Virtual Reality and presentation skills training

Mikropoulos and Natsis [7] describe Virtual Reality (VR) as "technologies that support the creation of synthetic, highly interactive three dimensional (3D) spatial environments that represent real or non-real situations." Users have to wear a head-mounted display (HMD), that is a head-mounted set of VR goggles in combination with headphones and (often) hand-held controllers. When wearing the HMD, the users can't see the real world outside themselves anymore. Instead, they see a 360 degree virtual world that is projected inside the HMD. When the users turn around or turn their heads, they see what is next to them or behind them.

In the case of presentation skills training in VR for example, the application gives the users a first-person perspective of a presenter on a stage. The users find themselves on this virtual stage in front of an audience that is looking at the user. Behind the user there is often a screen on which the user's PowerPoint slides are

projected (most applications allow users to upload their slides in advance into the VR application, so they can practice their presentation with their own slides). In some of the more advanced VR applications, the users can move around through the virtual room and when they move, the eyes of the audience will follow them. Some applications even allow the level of audience engagement to be set, ranging from an audience that appears highly engaged (e.g., nodding in approval, looking alert and interested, keeping their eyes on the presenter, looking friendly) to an audience which appears disengaged (e.g., sitting with their arms folded, looking at the ground, looking at their phone, yawning).

1.4 One of the key attributes of VR: Presence or the feeling of 'being there'

One of the attributes that are assumed to be central to VR technology, is VR's capacity to induce a strong sense of presence or psychological immersion in the user. Witmer and Singer [8] view this as a "psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" (1998, p. 227). Many other authors refer to this psychological immersion as 'presence', the psychological perception of being "there," within a virtual environment in which the person is immersed (Witmer & Singer, 1998). Onwards we will use the term 'presence'.

Several factors have been found to influence the level of presence, both from the side of technology as from the side of the users. An example of the role of technology in inducing presence is offered by Freeman and colleagues [9], who found that virtual environments that allow or even stimulate the users to act and move around, are associated with higher levels of presence. But characteristics of the users might also play a role. It may be that for some persons it is easier to experience presence than for others. Weibel et al. [10] for example, found a positive relation between the level of presence on the one hand and the personality traits Neuroticism, Extraversion and Openness to Experience on the other hand.

1.5 Research questions

The main question in this study is: Can a VR environment provide students with a realistic context for practicing presentation skills in the context of a technical university? Will the students feel that they are "really there", in that (virtual) lecture-room in front of an audience? In order to answer these questions, we have the following sub-questions:

1) To what extent does a VR training of presentation skills induce a sense of presence in students?
2) Does the level of engagement of the virtual audience, as expressed by their nonverbal behavior, affect the students and their sense of presence?
3) To what extent do personality traits (Extraversion, Neuroticism, and Openness to experience) moderate the students' sense of presence and their response to the audience's level of engagement?

2 METHODOLOGY

2.1 Design

In this study we use a mixed-methods approach. In the quantitative part, within-subject and between-subject designs are used. The qualitative part consists of semi-structured interviews with the respondents.

2.2 Respondents

In this study, 46 students from a technical university participated. Thirty-four female participants and 12 male participants participated. The mean age of the participants was 23.41 years (SD = 3.99, ranging from 18 to 34 years old).

2.3 Instruments

Hardware and software

The VR hardware that was used in the study was an HTC Vive set. The software was produced by Brainstud. In this application, users can practice their presentation on a virtual stage. PowerPoint slides can be uploaded in advance of the practice session. During the practice session, the slides are displayed in the virtual environment. The engagement level of the audience can be controlled by the instructor. This level can range from 0% (highly disengaged) to 100% (fully engaged). When the engagement is at the lowest level, the virtual public looks down, talks among each other and appear uninterested. When the virtual public is fully engaged they nod every now and then, and they show interest in the talk by looking at the participant. The instructor can vary the level of engagement during the presentation. He or she also can let phones ring in the audience, or let the audience give a round of applause.

Questionnaires

Sense of presence

The Igroup Presence Questionnaire (IPQ) (Schubert et al., [11] was used to assess the extent of sense of presence. The IPQ is a combined questionnaire constructed from previous published validated questionnaires [12]. The subset used in this research contained 14 items about the extent of sense of presence a participant experienced when standing inside the virtual environment. Participants rated each item on a seven-point Likert scale. The IPQ measures several constructs of presence: Spatial Presence (SP) (e.g., “I had a sense of acting in the virtual space, rather than operating something from outside”), Involvement (INV) (e.g., “I was not aware of my real environment”), Experienced Realism (REAL) (e.g., “How real did the virtual world seem to you?”), and one general item measuring presence, called General Presence (GP) (e.g., “In the computer-generated world I had a sense of ‘being there”).

A reliability check was carried out to measure the internal consistency coefficient of the IPQ. The seven-item scale showed adequate internal reliability with a Cronbach’s alpha of .78 for the results of the IPQ disengaged public and .79 for the results of the IPQ engaged public. Principal axis factoring with oblique rotation

confirmed the presence of the four IPQ factors in our data: Spatial Presence (SP), Involvement (INV), Experienced Realism (REAL), and General Presence (GP).

Personality traits
The NEO Personality Inventory (NEO-FFI) was used to assess the participants' personality in terms of the three dimensions extraversion (e.g., ''I am spontaneous''), openness to experience (e.g., ''I have a very active imagination''), and, neuroticism (e.g., ''Frightening thoughts sometimes come into my head''). This set of subscale consisted of 26 items and turned out to be reliable (with Cronbach's alphas of .86, .80, and .65 respectively). The participants rated each item on a 5-point Likert scale.

Semi-structured interview
After completing the two questionnaires a semi-structured interview gave insight into the overall VR experience. For example, "How aware were you of us being in the room?" and "Did you notice any difference in the type of public?".

2.4 Procedure

At first, permission was asked for conducting this experiment to the ethics committee of the University of Twente. The participants were asked for consent, before participating. All participants were informed in advance about the purpose of the study. They were asked to prepare a short presentation (max. 5 minutes) about their topic of choice, before attending the experiment. They also received a link to an online questionnaire to assess their personality. Participants were asked to fill out this questionnaire before the participated in the experiment. During the experiment, participants presented one time for a disengaged virtual public and one time for an engaged virtual public using the VR speech application, with a small break in between. Counterbalancing was applied, so in one condition, participants started with presenting for an engaged audience, followed by presenting for a disengaged audience. In the other condition, particants started with a disengaged audience followed by presenting for an engaged audience.

On the day of the experiment, each participant was exposed to the virtual environment to get familiarized with the technology before starting his or her presentation. The participants did not receive any feedback during or after their talks. Furthermore, the researcher was unaware of the participant s' NEO-FFI scores.

After each presentation, participants were asked to fill out a questionnaire about their experienced sense of presence, based on the Igroup Presence Questionnaire (IPQ) [11]. The presentations were audio and video recorded. The level of engagement of the virtual public was at the discretion of the researcher. For the public who was fully engaged, the engagement was set at 100%, hereinafter referred to as the engaged public. For the public who was disengaged, the engagement was set at 0%, hereinafter referred to as the disengaged public. To equalize the experience across participants in the experiment, a mobile phone rang in the virtual environment at 2 min 30 when presenting for the disengaged public. The public applauded only when the participants finished their presentation for the

engaged public to emphasize the positive ambiance. For ethical reasons, participants who presented for the disengaged public the second time were debriefed and told that the negative reaction from the audience was not due to their talk. At the end of the second and final presentation, a semi-structured interview was taken by the researcher to gain more insight into the overall VR experience of the participant. The overall experiment lasted 60 minutes for each participant.

3 RESULTS

3.1 Presence

First, a comparison was made between the experienced levels of presence when presenting for an disengaged audience versus presenting for an engaged audience. The average IPQ scores are displayed in Table 1.

Table 1. IPQ scores when presenting for disengaged and engaged audiences

	Disengaged audience			Engaged audience	
	Mean	SD		Mean	SD
Spatial Presence (SP)	4.51	0.75		4.67	0.65
Involvement (INV)	4.77	1.11		4.82	1.03
Experienced Realism (REAL)	3.93	0.99		4.16	0.98
General Presence (GP)	5.17	1.12		5.33	1.10
Average IPQ score	4.60	0.79		4.74	0.68

A paired-samples t-test was carried out to compare the mean IPQ scores when presenting for a disengaged or engaged engaged audience. Results indicated that Experienced Realism was significantly higher when presenting in front of an engaged audience as compared ot presenting for a disengaged audience ($t(45) = -2.66$, $p < .05$). No significant differences were found within the subscales Spatial Presence, Involvement, General Presence, or the average IPQ score.

To facilitate the interpretation of the sense of presence (IPQ) scores, we provide some benchmark IPQ scores reported in other studies. It should be noted that in all cases, 7-point Likert scales are used, however in those other studies, they are scored from 0-6. In our study, we score them from 1-7. In order to be able to compare the scores, we have added 1 point to the scores of the other studies, so they are now in the 1-7 range as well. The benchmark data come from three sources. The IGroup [11; 13], the inventors of the IPQ. They have reported IPQ scores of participants playing two highly immersive games, Tomb Raider and Half Life. Second source is a study by Buttussi and Chittaro [14] in which they offered a safety training in a virtual environment in which users experienced a full emergency evacuation of a commercial twin-aisle, narrow-body aircraft. The third source is a study reported by Peperkorn, Diemer, and Mühlberger [15]in which they studied a VR exposure therapy application aiming at the treatment of spider phobia. The benchmark scores are displayed in Table 2.

Table 2. IPQ benchmark scores

	Tomb Raider [13]	Half Life [13]	Safety training [14]	Spider anxiety [15]
	Mean	Mean	Mean	Mean
Spatial Presence (SP)	4.06	4.99	4.90	3.95
Involvement (INV)	3.40	4.27	5.15	3.20
Experienced Realism (REAL)	2.92	3.34	3.81	4.57
General Presence (GP)	4.00	4.93	4.75	4.45

When we compare the benchmark scores in Table 2 with the scores obtained in our study (see Table 1), we see in our study, the levels of reported spatial presence are mid-range, the levels of involvement are relatively high, experienced realism is also relatively high, and our level of general presence is the highest of all studies.

3.2 Personality traits

Neuroticism

The role of the personality trait Neuroticism was investigated in two ways. First, it was assessed if the participant's sense of presence (that is, their IPQ scores) with an engaged audience, with a disengaged audience, and the difference between those scores, was affected by the participant's level of Neuroticism. A repeated measures ANCOVA was carried out with IPQ scores (with engaged versus disengaged audiences) as within-subject factor and Neuroticism score as covariate. The analysis showed that the effect of audience engagement on the sense of presence was not significant, and neither was the role of the covariate Neuroticism.

Second, we split up the group of participants in a low Neuroticism group and a high Neuroticism group, using a split-median approach. Then, we tested for possible interactions with the effect of audience engagement on sense of presence. The repeated measures ANOVA showed that the interaction was not significant.

Extraversion

For the personality triat Extraversion, the same analyses as for Neuroticism were run. The repeated measures ANCOVA, showed no significant role of Extraversion. In the media-split procedure, where a group of participants scoring relatively low on Extraversion with a group scoring relatively high on Extraversion, did not show a significant difference.

Openness to experience

The same analyses were repeated for personality trait Openness to experience. The level of Openness to experience did not play a significant role as covariate in the effect of audience engagement on sense of presence. Also, a comparison between a group scoring relatively low on Openness to experienct to a group scoring relatively high, did not show a significant difference between those groups with regard to how their sense of presence was affected by audience engagement.

3.3 Results interview

After completing the second talk a semi-structured interview was held to gain more insight into the overall experience. Despite the fact that the participants were facing a virtual audience, they stated that they felt it was more real than expected (e.g. “Although it didn’t seem real, I was fully captivated in the virtual world”). The majority (38) of the participants indicated that they were unaware that the researcher was in the (same) room (e.g. “I completely forgot my environment”). Eight participants stated that they were only the first time aware that the researcher was in the (same) room. Forty-five participants were able to successfully distinct the disengaged public from the engaged public, one participant only failed to recognize a difference in the type of public. A summary of the reactions can be found below.

Comments regarding presenting for a disengaged audience

The reactions on the speeches for the disengaged public were inconsistent. Twelve participants indicated that the disengaged public distracted them. Many reported feelings of confusion and a tendency to forget what they wanted to say. Moreover, one participant stated: “I felt insecure because they seemed bored.” Different from some participants who argued that the disengaged audience did not influence them, what made it easier to give the presentation, for instance: “I felt less nervous because they didn’t seem to care. You can make mistakes as they would not notice it”, and “The public didn’t look, that makes it easier. You are less distracted.”
A further finding was that 12 participants felt like talking to a wall. One participant recalled: “After a while, I tended to say that if they don’t want to listen, they rather go.” And another one stated that he was just going to finish the 5 minutes without paying attention to the public. Participants described the disengaged public as ‘demotivating’, and ‘uncomfortable’.

Comments regarding presenting for an engaged audience

Participants’ reactions regarding the presentation for the engaged public were in contrast to the disengaged public more consentient. Twenty-one of the participants indicated that speaking in front of the engaged public was more motivating than speaking in front of the disengaged public. One participant commented: “For the second one (engaged) I felt the time moved on faster”, and “For the second one (engaged) I didn’t have to concentrate that much, because I had the engagement of the audience, so it was easier.” “In the second presentation (engaged) I used more body language and I was more into it.” Another indicated: “And also people looking at me, I felt better”. Though, there were some idiosyncratic reactions amongst the participants. Nine participants argued that the engaged public was making weird gestures with their hands. One stated that he had a hard time interpreting the engaged public and one participant recalled: “I found the second (engaged) public annoying. You are watching them and they are making gestures which don’t make sense.”

4 CONCLUSION AND DISCUSSION

The results of our study show that a VR environment for the training of presentation skills is capable of inducing relatively high levels of presence, the feeling of being there. In that sense it can compete with highly immersive computer games such as Tomb Raider and Half Life. Actually, the average reported levels of general presence, the sense of being there, were in our study even higher than in the benchmark studies.

In our study, we also looked at the effect of the level of engagement of the audience on the experienced sense of presence of the user. The engagement level of the audience was expressed by their non-verbal behavior, and two conditions were compared, one with a highly engaged audience, and one with a highly disengaged audience.Our quantitative data do not show much of an effect. Only for the level of experienced realism, engagement level makes a significant difference. In case of an engaged audience, the students on average rate the experienced realism higher. For all other cases, no differences were observed. Interestingly though, is that our qualitative data, that is the data from the interviews, indicated that the engagement level had quite a profound effect on the user experience. Apparently, our quantitative measures were not fully capable of capturing the effects of audience engagement. In a future study, this point needs reconsideration.

We also conclude that personality traits did not seem to play any role of significance in our data. This might suggest that students' responses are not or only to a minor extent dependent on their personality traits. From an educational point of view, that might be good news. No differential effects are to be expected from personality. Still, since personality has been found to play a role in other studies, this needs to be investigated further.

Limitations of the current study are, for example, that in the study we did not measure the training effects of the VR training, the training effects compared to "traditional" trainings. And also, we did not compare the level of presence and realism to non-VR conditions, varying from practicing in one's own room to practicing in front of a real audience. However, at this moment we are running studies to address these points.

For now, we conclude that a VR environment for the training of presentation skills can be promising for technical studies as a means for practicing and training of students in more or less realistic circumstances.

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GAME-BASED LEARNING OF MULTI-CULTURAL TEAM COMPETENCIES THE EFFECTS OF PLAYING BAFÁ BAFÁ ON ATTITUDES AND SKILLS OF FUTURE ENGINEERS

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ABSTRACT

Learning multi-cultural team competencies is important for engineering students to prepare for an increasingly global workspace. We evaluated the game BAFÁ BAFÁ with groups of Master students from varying engineering programmes using a mixed-methods approach. The game experience of 118 participants was measured. These participants experienced the game overall positively, although difficulties to understand other players in the game triggered mild stress and confusion. 91 respondents also completed questionnaires before and after the game about certain attitudes, skills, and values related to working with people from other cultures: willingness (attitude) and ability (skill) to understand those people; and appreciation (value) of working with them. We used paired t-tests and qualitative analysis to determine the game's effectiveness: after playing the game the players' willingness increased significantly ($t(90) = 3.6$, $p=.001$), but their ability to do so decreased significantly ($t(90) = 3.3$, $p=.001$) and their appreciation remained constant ($t(90) = 1.3$, $p=.195$). The qualitative responses supported our quantitative results: after playing the BAFÁ BAFÁ game, players were more willing to understand people from other cultures. Moreover, players had become more aware of their own shortcomings in understanding people from other cultures. Finally, the learning effects were likely not caused by a test effect, since the appreciation (value) of working with people from other cultures had not increased after playing the game. We concluded that the BAFÁ BAFÁ game is a powerful instrument to embark upon

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teaching multi-cultural team skills, and therefore, to train more culturally aware engineers.

1 INTRODUCTION

Engineering traditionally focuses on addressing applied problems through technology. However, as we come to understand the complexity, interconnectedness and interdisciplinarity of most engineering problems, we realise that future engineers need to be prepared to work as multi-disciplinary problem-solvers with people from very different cultural backgrounds. This calls for new learning domains and learning approaches.

1.1 Multi-cultural teams and intercultural learning

Cultural backgrounds shape how people think, feel, and act across a range of professional and life situations. Culture determines what is perceived as good or bad, forbidden or permitted, abnormal vs. normal, or irrational vs. rational [1]. The difficulty that arises in working with culturally diverse others is that what one assumes as normal and proper can be completely the opposite for someone else. And even if we see and interpret obvious aspects of culture as expressed in particular behaviours, customs or language, we remain blind to the underlying unspoken assumptions, values and ways of thinking. This can easily lead to misunderstandings and wrong interpretations, hurt feelings, if not a breakdown of collaboration in culturally diverse teams. The negative impacts of ignoring substantial differences in cross-cultural team work and business, even among well-trained top-level managers, are well-known [1,2].

Intercultural learning, gaining awareness of one's own and others' culture, does not come easily. Cultural change and learning is *"[…] intrinsically difficult, because the re-examination of basic assumptions temporarily destabilizes our cognitive and interpersonal world, releasing large quantities of basic anxiety"* [3]. To unlock culture, it is important to look beyond national culture to explain differences and commonalities between people. Research supports that any social group has cultural traits that distinguish it from other comparable groups, be it a family, organization, or society at large. Also, professions like engineering or economics are considered to have particular and distinguishable cultures [4,5]. For instance, the distinguishing characteristics of engineers mentioned in the literature include being technophile and practical while also holding analytically-minded and substantial scientific expertise, being competitive, technically self-confident and valuing individual autonomy, next to uncommunicative and socially awkward tendencies [6].

Concluding, multi-cultural teams are at risk of collapsing if team members with different national, professional, or other cultural backgrounds are not equipped for intercultural learning. If even culturally-trained top-level managers struggle to overcome issues in multi-cultural interaction, how can we effectively bring such learning to the MSc engineering classroom? Below, we will explore the opportunities for this provided by immersive teaching approaches such as a game.

1.2 Game-based learning with BAFÁ BAFÁ

BAFÁ BAFÁ is a well-known simulation/game to learn about culture and diversity [7,8]. Various studies have been conducted to evaluate the BAFÁ BAFÁ game and its effects on players. For instance, Glover *et al.* [9] found significant increases in tolerance for ambiguity and significant decreases in dogmatism among undergraduate educational psychology students who played the game. Pruegger and Rogers [10] compared two methods of training cross-cultural sensitivity: playing BAFÁ BAFÁ vs listening to a presentation about cultural differences. Although quantitative measurements could not show a difference between the two methods, a qualitative comparison did signal greater effects of the experiential approach using BAFÁ BAFÁ. More recently, Ong-Flaherty *et al*. [11] performed a qualitative study on using BAFÁ BAFÁ to raise cultural awareness among students of health professions, which supported earlier work about the game's effectiveness. Finally, Wendorf Muhamad and Yang [12] analysed quantitatively how the game influenced players' intercultural sensitivity and intercultural communication competence. They found significantly higher sensitivity and competence amongst players who had played the game when compared to a control group.
Concluding, the game BAFÁ BAFÁ was shown to be effective in teaching multi-cultural team competencies to students of various backgrounds, such as educational psychology and health care professions. In this paper we will aim to answer the question to what extent the game is effective when applied to groups of engineering students. Below, in section 2, we outline our methodology for studying the effects of the BAFÁ BAFÁ game on engineering students. In section 3, the results are presented followed by a brief discussion in section 4. Finally, we draw conclusions in section 5.

2 METHODOLOGY

We played BAFÁ BAFÁ with three different student groups from Delft University of Technology in the Netherlands. The first group consisted of second-year Masters students subscribed to the course Joint Interdisciplinary Project (JIP). JIP students worked with other engineering students from all over the world and from and a wide range of engineering disciplines and played the game as part of the project kick-off. The second group consisted of first-year Civil Engineering students from the Master track on Environmental Engineering (EE) who played the game as part of the course Integrated Project. The third group comprised first-year Masters students from the Engineering and Policy Analysis (EPA) programme who played the game as part of their onboarding activities.

2.1 Game session design

Each game session begun with a 5-minute ice-breaker game and a plenary briefing after which the game was started. In the game, players are randomly assigned to either of two groups or 'cultures': the Alpha Culture is oriented towards strong social relationships, hierarchy, and close physical proximity; whereas the Beta Culture is more egalitarian, competitive, and distant. The game starts with both cultures, in separate rooms, getting themselves familiar with the habits, rules, and interaction

patterns of their culture. For this we had developed video clips to explain the rules of the players' new culture in English. The videos were supplemented with English subtitles to support non-native English speakers. Game facilitators then helped the players to practice interacting with other members of their culture according to the rules that had been explained.

In the second phase of the game, both cultures exchange group members with the other culture. In the first exchange round, an observer visits the other culture, watches the members of the other culture interact with each other, and reports back their observations. In subsequent rounds, small groups of players exchange with the other culture and interact with their hosts. The players are explicitly requested not to explain the rules that govern the behaviour of members of a culture. Instead, visitors should learn these rules through trial and error. Every time a group has visited the other culture, they report back to the members of their own culture. Although the rules for behaving in each culture are relatively easy to learn, the resulting behaviour looks rather complex to an outsider who is not familiar with them: it is very difficult to deduce the rules from the observed behaviour. Moreover, if visitors do not know how to follow the social codes of the other culture, they run the risk of being ignored by their hosts or even expelled from the room. As a result, visitors need to be very attentive and careful when trying to interact with the other culture.

After all players had visited the other culture, the game was ended and all players were gathered in the plenary space. Here, a debriefing session was held consisting of two phases: first we gathered qualitative data on the players' game experience; second the players held small group discussions about the cultural differences in the game followed by a plenary discussion. At the end of one of the courses (EE students), feedback about the course learnings were collected in-class as well as via individual written reflections.

2.2 Research design

Following the framework by Mayer *et al*. [13], we applied a mixed methods approach to studying the effects of the BAFÁ BAFÁ game both quantitatively and qualitatively. First, we used questionnaires before and after the game to quantitatively measure:

- Several background variables of players (age, gender, frequency of playing games in their daily lives; pre-questionnaire only)
- Seven dimensions of the players' game experience [14] (post-questionnaire only): five positive dimensions (competence, immersion, flow, challenge, and positive affect) and two negative dimensions (tension and negative affect). Each dimension was measured by averaging the scores on two items provided by participants through self-report (scores on 5-point Likert scales). The overall game experience was calculated by averaging over the scores for the five positive dimensions and the inverted scores for the two negative dimensions.
- Changes in certain attitudes, skills, and values that resulted from playing the game. To measure the latter changes we developed three constructs: (1) willingness (attitude) and (2) ability (skill) to understand team members from

other cultures; and (3) appreciation (value) of working with them. Each construct was measured through self-report by scoring multiple items on a 7-point Likert scale in the pre- and post-questionnaires.

We used paired t-tests to determine the significance of changes in players' attitude, skill, and value and thus measured the effects of the game sessions for the complete sample of students (N=91). Independent-samples median tests were applied to determine the effect of the game sessions and background variables on the game experience and game effects. We used this non-parametric test instead of the more common ANOVA due to the relatively low number of respondents in one of the game sessions.

In addition to the quantitative measurements, we asked players qualitatively about their learning experience through open questions during the plenary game debriefing (immediately after the game), in the online post-questionnaire (individually and anonymously), and during the course evaluation (EE students only).

3 RESULTS

A total of 118 participants from all game sessions completed the Game Experience Questionnaire. 91 participants completed the attitude, skill, and value measurements in both the pre-survey and post-survey. The age of respondents ranged from 20 to 33 years old (M=24, SD=2). Of all respondents 28% were female and 47% were male (25% gender diverse or unknown). Below we report on our respondents' game experience (Section 3.1) and the measured game effects (Section 3.2).

3.1 Game experience

During the post-game debriefing sessions students were asked about their experiences when visiting the other culture in the game. The great majority reported mild stress (such as feeling 'awkward', or 'not belonging') or indicated confusion ('confused', 'weird').

The scores on all seven dimensions of the Game Experience Questionnaire [14] as well as the overall game experience, averaged over the entire sample, are shown in Fig. 1.

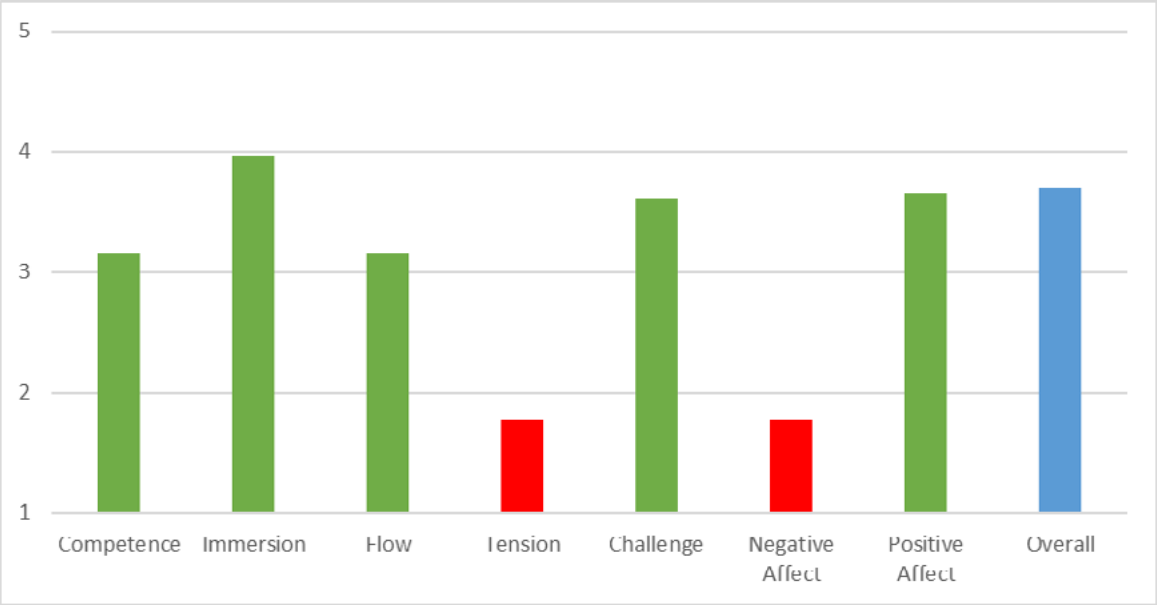

Fig. 1. Sample averages for seven dimensions of the Game Experience Questionnaire [14] (five positive dimensions (green) and two negative dimensions (red)) and the overall score (blue). Items were scored on a 5-point Likert scale ranging from 1 (low) to 5 (high).

The figure shows that all positive dimensions (green) score on or above the theoretical average value of 3 (possible scores range from 1 to 5). Immersion has the highest average score (M=4.0, SD=0.6), whereas the negative dimensions (red) have the lowest averages (both Tension and Negative affect: M=1.8, SD=0.8). This means that respondents reported on average a more positive than negative game experience.

Independent-samples median tests were conducted to determine the effects of the game session, the frequency of participants playing games in their daily lives and the participants' age, country of origin, and gender on the overall game experience. No statistically significant effects were found at the $p<.05$ level.

3.2 Learning effects

We measured learning effects of the game in two ways. First, participants reported several types of take-home messages in the post-game questionnaire. Some mentioned quite specific learning outcomes, while others stated more general insights they had gained. Examples of specific learnings are:

- *"It's very hard to live under a brand new culture. It's common to make mistakes and offend others."* - female Chinese student, age 22.
- *"The difference between an intrinsically competitive society and a social dynamic driven society is high."* - female Indian student, age 24.

Examples of more general insights are:

- *"It is important to spend time learning about other cultures before pursuing your own goals."* - male South African student, age 22.
- *"When you go into another culture you try to understand them but you are only looking for the things that you find important in your own culture."* - female Dutch student, age 21.

Some respondents referred explicitly to what they learnt during the debriefing after the game had ended (when they discussed the rules of the different cultures):

- *"It is good to explain how things work in your culture."* - male Dutch student, age 23.
- *"Talking about differences is essential to gaining understanding [of other cultures]"* - female Canadian student, age 30.

Second, as part of their course evaluation, the EE students highlighted the importance of including intercultural and team work training into their studies and how the game had left a lasting impression. The individual reflections illustrate the intercultural learning outcomes obtained during the course that started with playing BAFÁ BAFÁ.

- *"Being in an international group that you do not know even their culture, it was so stressful for me but in the next steps, I became able to adapt myself to these situations."* – male Iranian student, age unknown.
- *"[…] I experienced both the difficulties and power of combining people from different cultures."* – female Chinese student, age unknown.
- *"I did learn a lot on different cultures and how to tackle problems within a project group. […] now I will have some understanding of how to deal with it or even resolve the problems."* – female Dutch student, age unknown.
- "*The differences in culture is something that should be always on your mind. It's applicable in almost every situation and really helped our team work together very pleasantly. […]*" – female Dutch student, age unknown.

3.3 Effects on willingness, ability, and appreciation

The willingness and ability to understand team members from other cultures and the appreciation of working with them, are reported in Table 1.

Table 1. Willingness, ability and appreciation averaged over the entire sample before and after the game session. Also shown are the results of student-t tests to determine the significance of the differences between the average values before and after the game session.

	Before		After		t(90)	p-value
	M	SD	M	SD		
Willingness	4.6	0.8	4.8	0.8	-3.603	0.001
Ability	5.0	1.0	4.7	1.1	3.320	0.001
Appreciation	4.9	1.0	5.0	1.0	-1.305	0.195

We conducted student-t tests to determine the significance of the differences between the average values before and after the game session. The results, shown in Table 1 above, indicate that the average Willingness score has increased significantly from 4.6 to 4.8. In contrast, the participants reported a

significant *decrease* of Ability from 5.0 down to 4.7. Finally, Appreciation increased from 4.9 to 5.0, but not significantly at the $p<.05$ level.
As was done in the analysis of game experience, we conducted independent-samples median tests to determine the effects of the game session, the frequency of participants playing games in their daily lives, and the participants' age, country of origin, and gender on the (change in) willingness, ability, and appreciation before and after the game session. No significant effects were found.
The results bear three main implications. First, after playing the game participants were on average more willing to understand team members from different cultures. Second, after playing the game participants felt on average less able to understand team members from different cultures. Third, after playing the game participants did not appreciate working with people from different cultures more or less than before the game.

4 DISCUSSION

Our results suggest that playing BAFÁ BAFÁ leads to deeply felt, lasting, affective experiences, both positive and negative. Recent research by Tyng *et al.* [15] shows the importance of affective experiences for learning and memory development. Negative affect, such as confusion or frustration, serves to increase focus and attention, where mild-intensity, short-duration stress facilitates learning [16]. In contrast, positive affect triggers self-motivation and satisfaction [17] thus enhancing curiosity and exploration, preparing one to learn and remember. Therefore, the affective experience of playing BAFÁ BAFÁ is likely an important factor in the learning effects of the game.
Also, we noticed that the game triggered thought processes beyond the direct experience of players, inviting them to elaborate on the message of the game. Many of the reported take-home messages related to the debriefing phase of the game session, which marks the importance of a debriefing to make tacit learnings explicit [18].
Comparing our results directly to earlier work, such as the recent study by Wendorf Muhamad and Yang [12], is difficult due to differences in experimental designs and measurement instruments. However, comparing interpretations of the studies is feasible. For instance, like in the earlier work, our results suggest that the game motivates players for intercultural learning: we measured a significant increase in willingness to understand people from other cultures, where Wendorf Muhamad and Yang found significantly higher engagement, communication motivation, and interaction attractiveness scores (i.e. proxies of learning motivation), next to high interaction enjoyment (positive affect). However, when looking at skill development our study may have yielded other outcomes than the earlier work. Our qualitative and quantitative measurements showed a decrease in the players' ability to understand people from other cultures after playing the game. We interpret this outcome as follows: players had become increasingly aware of the difficulties they encounter when they interact with people from different cultures. Or, in terms of the "conscious competence" learning model [19]: players had become *consciously*

incompetent after playing the game. This finding may contrast the results of Wendorf Muhamad and Yang [12]. The latter reported higher intercultural communication skills in the group that played the game when compared to the control group. This could mean that playing the game *in*creased the ability to communicate with people from other cultures in the earlier work, where it *de*creased the ability to understand people from other cultures in our study. More research is needed to understand the difference. It could be due to various factors such as the slight difference in the constructs that were measured, the differences in the participants' background, or the ways in which the game and debriefing were facilitated.
Finally, we found that the reported value of working with people from other cultures did not change after playing the game. This absence of change can be interpreted as a sign of the reported learning effect not being caused by a 'test-effect' [20]. A test-effect in questionnaire research causes items in a post-questionnaire to be scored higher than similar items in a pre-questionnaire, for the simple reason that attention has been devoted to those items in the pre-questionnaire.

5 CONCLUSIONS

We used a mixed-methods approach to explore the effectiveness of the BAFÁ BAFÁ simulation/game to teach multi-cultural team competencies to MSc engineering students. Our respondents reported an overall positive game experience, although the game also triggered some negative emotions when it concerned players' abilities to understand other players in the game. We argued that these mild intensities of stress contributed to deep learning experiences at multiple levels of abstraction, ranging from rather specific lessons learnt to more general insights about multi-cultural teamwork. In line with the qualitative outcomes, our quantitative analyses showed significant increases in players' willingness to understand people from other cultures, after playing the game. In contrast, players reported a significant decrease of their ability to do so, which may be interpreted as players becoming *consciously incapable*, which is the first step towards mastering multi-cultural team skills. Finally, players reported no significant change in their appreciation of working with people from other cultures, which was expected from the experimental design and likely rules out possible test-effects in the response to our questionnaires. We concluded that the BAFÁ BAFÁ game is a powerful instrument to embark upon teaching multi-cultural team skills, and therefore, to train more culturally aware engineers. Based on the findings, to create intercultural awareness and facilitate learning, we suggest to include games such as BAFÁ BAFÁ ideally during early stages of a programme or course. Closer study of the mechanisms underlying BAFÁ BAFÁ outcomes and their effect on learning is needed for evidence-based design of intercultural training as part of engineering programmes. Other opportunities for future work include the use of more established scales for intercultural sensitivity and intercultural communication competence in our quantitative measurements, in order to compare our outcomes to those of other authors. Also, we recommend to study in more detail why, after playing the game, respondents reported a decrease in their ability to understand team members from other cultures.

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SUSTAINABLE DEVELOPMENT COMPETENCIES FOR ACHIEVING THE SDGS: ENGINEERING STUDENTS AND INDUSTRY REQUIREMENTS

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ABSTRACT

This paper will provide an insight into how French engineering students and employers perceive the competencies needed to meet the UN Sustainable Development Goals (SDG). It draws on the findings of two exploratory focus group studies carried out in the context of the A-STEP 2030 European Project. Our results indicate significant differences in the awareness of sustainability goals among respondents, but a relatively high level of convergence around the skills and competencies that appear most necessary for attaining sustainable development. The respondents considered that technical knowledge and skills were adequately included within French engineering school curricula, yet they felt that achieving the SDGs would demand that more emphasis be placed on the development of transversal skills. According to our results, engineering schools need to more comprehensively integrate transversal skills and competencies. Our findings also suggest that this may best be achieved via

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interdisciplinary teaching and an increased use of project-based education (PBE) and learning carried out in a real work context.

1 INTRODUCTION

Sustainablity education is definitively a crucial element in addressing the '2030 Agenda for Sustainable Development' established by the United Nations in 2015. Engineers in particular will play a central role if the 17 Sustainable Development Goals (SDG) are to be met. Consequently, engineering schools ought to prepare engineering students to meet these challenges. This implies that they are able to address the kind of complex and wicked problems that sustainable development presents. Nevertheless, and even if sustainability education has gained a considerable institutional momentum over the past few years, there remains ambiguity regarding which competencies are needed for future engineers. In this study, we investigate how this question is answered by engineering students and industrial organisations currently on opposite sides (supply and demand) of the employability market in France.

2 LITERATURE REVIEW

It is widely recognised that the engineering profession has a major impact on society and that it will play a central role in addressing the SDGs. Engineers working towards achieving sustainability have to be creative and innovative. They must also adopt a future-oriented way of working and thinking [1]. During the last two decades, we have witnessed a transition from the traditional role of engineering which involved supporting industry and providing technical solutions to industrial problems towards a new and more inclusive role within society. This new role embraces not only technical approaches but also recognizes human and social factors [2].

This evolution of the role of the engineer requires the integration of new competencies in sustainability into the engineering curriculum. Based on a recent literature review [3] carried out in the context of the A-STEP 2030 project, even if sustainablity competencies are considered as critical for graduate engineering students, there is a lack of consensus in the educational literature regarding the relevant competencies.

Following Wiek et al. [4], one can distinguish between 'regular' competencies and 'essential' competencies. We consider technical competencies (including technical knowlegde, skills, aiblities, capabilities, capacities and other related concepts) that are systematically included in engineering academic programs as regular competencies. As a matter of course, engineering schools are putting emphasis on these competencies, which are considered as the core competencies of the engineering profession. Transversal competencies such as anticipatory thinking [5], integrated solutions [6], social participation [7], sustainable entrepreneurship [8] and normative or action competencies [9] are essential for meeting the sustainabilty challenge. However, these competencies are not entirely integrated into traditional academic engineering programs and are thus by and large neglected by engineering schools.

3 APPLIED METHODOLOGY

For the data collection of our exploratory study, we opted for the focus group method, a widely used and popular data collection method in qualitative research. This allowed us to inverstigate our research question by generating debates which were informed by group dynamics [10].

This method, which involves human participants, requires ethical considerations to be taken into account. We thus sought ethical approval from the Ethics Committee of TU Dublin before beginning the data collection. Focus group participants received written information about our research project, focus group study objectives, confidentiality and the possibility of withdrawal. They were asked in advance to give written consent.

We completed two focus groups with engineering students and corporate representatives. For the student focus group, 9 participants from bachelor to master level were selected with the help of the local BEST (Board of European Students of Technology) student association. For the corporate focus group, 8 participants from diverse industries (electronics, automotive, energy, naval,…) were selected with the help of a local Alumni association.

As this study was part of the A-STEP 2030 European project, we carried out the focus groups in a very standardized way, following a collectively agreed upon Focus Group Handbook. Focus groups were undertaken in French as it was the native language of the participants and thus facilitated discussion. We undertook the following procedure:

1. At the beginning, participants were asked about their awareness of SDGs.
2. As a second step, they were asked to consider the skills needed for engineers to meet SDGs and to present their choices in a brainstorming session.
3. The third step consisted of a deep discussion about their choices and reasoning.

The two focus groups were digitally recorded and transcribed. Only selected citations were translated into English.

For the data analysis we also followed a standardized and collectively approved thematical analysis framework. The qualitative data analysis process was carried out by two senior researchers. This allowed us to discuss the group dynamics and to include group interactions in our analysis [11].

4 RESULTS

Our findings show a particularly low level of SDG awareness among professional participants. The most surprising finding was that students' awareness of the SDGs can be described as moderate, which was lower than our expectations.

Concerning the competencies needed for achieving the SDGs, participating students defined the following requirements illustrated in Table 1 below:

Table 1. Unordered list of student participants' perception of competencies needed for SDG's

Competencies – Student focus group in France		
Technical skills	Holistic thinking	Open mindedness
Economic skills	Stress management	Agility
Digital skills	Creativity	Adaptability
Multidisciplinarity skills	Global Awareness	Emotional Intelligence
Decision making skills	Social Responsibility	Perseverance/Grit
Communication: Listening skills	Sustainability Awareness	Ethical Conscience
Critical thinking	Environmental Awareness	Personal engagement & agency
Life cycle thinking	General Knowledge	
Analytical thinking	Respect for others	

First, they outlined the importance of fundamental technical skills and digital skills complemented with economic skills. They were unanimous that technical skills are currently well-covered within the curriculum, arguing "all that is technical knowledge, we currently have it." They highlighted the need for economic skills, as "we are living in an economic world, we must have economic skills…that allow us to perceive the world today... especially for innovations". Surprisingly, they referred to relatively few application skills like multidisciplinary skills or decision-making skills.

Non-technical skills and competencies were considered by student participants to be vital for future engineers. They pointed out the importance of communication skills, and most particularly listening skills and ways of thinking (such as critical thinking, lifecycle thinking, analytical thinking or holistic thinking). However, they cited numerous attitudinal competencies related to their world views (a sense of social responsibility, environmental awareness, general knowledge or global awareness). They also highlighted character traits like adaptability, open-mindedness, perseverance/grit, respect for others, personal engagement, agency and ethical conscience.

Corporate focus group participants outlined the following required competencies for SDGs in Table 2:

Table 2. Unordered list of corporate paricipants' perception of needed competencies for SDG's

Competencies – Employers focus group in France		
Digital skills	Inter-cultural skills	Challenging the status quo
Mathematics skills	Collaboration	Social responsibility
Economics skills	Communication: Foreign languages	Respect for others
Design Skills	Respecting Diversity	Open-mindedness
Interpretation skills	Teamwork	Agility
Innovation	Creativity	Ethical Conscience
Project management	Convergent thinking	

For professional participants, similarly to students, “technical competencies are well taught in engineering schools;…this is their principal mission”. They pointed out that “digital skills are important, engineers need to know how to process information, how to protect it, how to use software even without being specialized in that domain” regarding a “strong and practical knowledge in applied mathematics” as equally important. For the application skills, they highlighted the relevance of innovation capacity and design skills as critical to the innovation process.

They put a particular emphasis on the non-technical competencies like intercultural skills, collaboration, teamwork, respect for diversity and “project management with multicultural partners who understand each other…and work together with people who do not have the same culture. When working in a team and everybody has good ideas and we get better results”. Related to these multicultural concerns, they called attention to the importance of “practical knowledge of foreign languages…this is much more than a basic knowledge of the English language”.

Similarly to student participants, they found attitudinal competencies important but were less focused on character. This is an interesting finding. Concerning ethical conscience, they highlighted the significance of “intellectual honesty that means not stealing others’ ideas” which was evoked several times. This finding demonstrates that industrial companies and organisations have a strong interest in innovation and creativity and their applicability for developing and protecting industrial patents. Comparing the results of students and employer focus groups, there is agreement regarding the fact that the technical competencies are well taught in French engineering schools. From these technical competencies, they single out digital skills as particularly important to engineers. As a matter of fact, technical skills should be combined with economic skills to provide a solid understanding for future engineers to face the challenges of SDGs. Concerning the non-technical competencies, creativity was outlined as an important skill for fostering innovation. We observed a strong convergence relative to attitudinal competencies such as social responsibility, respect for others, open-mindedness, agility and ethical conscience. Among these attitudinal competencies, the significance of social responsibility and ethical conscience were accentuated.

5 CONCLUSION

The main conclusion that can be drawn from our study is that there is a growing need for non-technical or transversal competencies, especially for all kinds of competencies related to the attitudes of future engineers. Our findings are broadly consistent with previous research available in the literature suggesting emphasis on “competencies considered essential for sustainability that have not been the focus of traditional education and therefore require special attention” [4, pp. 204]. The engineering students suggested the integration of these essential competencies into the curricula in a transdisciplinary way within the traditional technical education through an increased use of project-based education (PBE) carried out in a real work context.

The principal limitation of our study, in addition to the general limitations of qualitative studies, is its restriction to one engineering school. Within the framework of the A-

STEP 2030 project, future research involves the comparison of participating countries at a European level.

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ADAPTIVE LEARNING TECHNOLOGIES IN TUSUR UNIVERSITY

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Keywords: *Adaptive learning, Genetic algorithm, Ebbinghaus forgetting curve*

ABSTRACT

One of the popular educational technologies today is adaptive learning.
TUSUR has been conducting research in the field of adaptive learning since 2013. Models, algorithms, techniques, and software have been developed to create adaptive e-learning courses for a wide range of disciplines. These technologies are based on the elements of artificial intelligence and predictive analysis of the knowledge level (forgetting curve).
The presentation will show the experience of TUSUR University in the task of development and testing in the real educational process of an adaptive e-learning course. The basic approaches in content design will disclose as well.

1 INTRODUCTION

1.1 Project purpose and objectives

The need for continuous learning and the acquisition of new skills does not fit well with the concept of consistent, structured, static learning offered by familiar LMS systems. A training course in which the instructor designs the content and then presents it in a certain logical sequence is well suited for classical full-time education. But a modern online course must be so dynamic that it generates personal learning trajectories "on the fly". An adaptive learning course should be based on a model of the learner to offer him or her at any moment the optimal (in terms of knowledge level, presentation form, etc.) element of content.
Thus, the objective of the project is to develop an adaptive learning platform and to pilot it on the case of developing and implementing an adaptive learning course. For this purpose, the following tasks need to be solved:

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1. To design and implement an adaptive learning platform. This task has already been solved and the results have been published, so the development of the platform is not described in this article. Only general information about it is given.
2. To develop rules of preparation of learning materials as well as necessary tools for creating an adaptive course.
3. To implement and integrate an adaptive course into the learning process.
4. Evaluate the impact of using adaptive technology in training.

1.2 Project history

The Laboratory of Instrumental Modelling and Learning Systems (LISMO) of the TUSUR Institute of Innovation has been developing the concept of an adaptive learning platform since 2013 [1, 2]. The concept has been based on:
- Breaking down the learning material of the discipline into modules;
- dividing the competences learned in the course of the discipline into subcompetences (learning outcomes);
- measurement of students' knowledge level in each subcompetence on the basis of testing;
- extrapolation of students' knowledge level using Ebbinghaus forgetting curve [3];
- fixation of the studied material in long-term memory on the basis of repetition effect [4].

In 2017 the first software implementation of the platform was released [5, 6]. In 2018 for the National University of Science and Technology MISIS was created an adaptive course in the discipline "Chemistry" [7, 8]. This article describes its development and experience of its use in the learning process.

1.3 Difference from existing solutions

There are several companies on the market that offer ready-made solutions for adaptive learning. These include companies such as Knewton[2], Khan Academy[3], as well as Pearson Education[4], McGraw-Hill Education[5], and others. However, a number of factors hinder the use of the adaptive courses they offer in the Russian Federation in general, and in TUSUR in particular:
1. Language barrier. The overwhelming majority of disciplines in the Russian Federation are taught in Russian. Meanwhile, finding Russian-language adaptive courses from publishers in Europe or the USA is very problematic or impossible at all.
2. Availability of tools. Adaptive learning platforms from these companies and publishers are closed. That is, they certainly have their tools for filling adaptive courses with content, but they do not provide them for public access. Therefore, the development of new adaptive courses is only possible within these companies and publishers.

[2] https://www.knewton.com/
[3] https://www.khanacademy.org/
[4] https://www.pearson.com/
[5] https://www.mheducation.com/

3. A question of scale. From the previous paragraph follows the high cost of custom development of a new adaptive course, which is justified only if the launch of such courses has a high commercial potential and the number of participants in one course starts from 10,000 students or more.
Therefore, the development of an adaptive learning platform with open tools and the possibility of implementation into the existing LMS used in higher education institutions is relevant, making the development of their own adaptive courses appropriate even for small educational institutions.

2 METHODOLOGY

2.1 Content preparation

At the initial stage of developing an adaptive course, a team of methodologists should break down all the material of the discipline into modules and competencies. This is a rather time-consuming process.

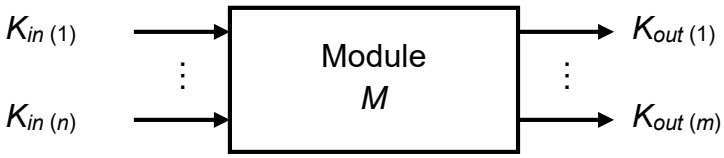

Fig. 1. General presentation of the module

Modules (Fig. 1) are indivisible, autonomous units, carrying enough information (text, graphic, multimedia) to unambiguously define the output skills and knowledge (competencies) that the trainee will acquire after mastering this module [1]. The competence tree is presented as a link diagram (or memory card). Further, for each module, a document (in the format of Microsoft Word, OpenOffice Writer, HTML, etc.) is prepared, including the module name, its content, as well as a list of questions for the test, allowing to check the level of knowledge of students on the output competences after studying the module. And, finally, a table (Microsoft Excel, OpenOffice Calc, etc.) is compiled for describing the links between modules and competencies. Thus, the set of modules and competences of an adaptive course forms a directional bipartite graph [2].

2.2 Algorithm for providing modules to students

If the stage of modules and competences design is completed responsibly, the adaptive course is able to work completely autonomously in the training process, independently deciding the further trajectory of training, providing students with training modules, testing their knowledge, and collecting analytics.
The general block diagram of the algorithm is shown in Fig. 2. Here P is the graph-path (the path in the graph, passing through the unexplored modules in such a way as to provide the maximum average level of remaining knowledge of a student at the moment of the end of course), S is the student model, consisting of the history of his learning, and individually selected coefficients of Ebbinghaus forgetting curves as well [3].

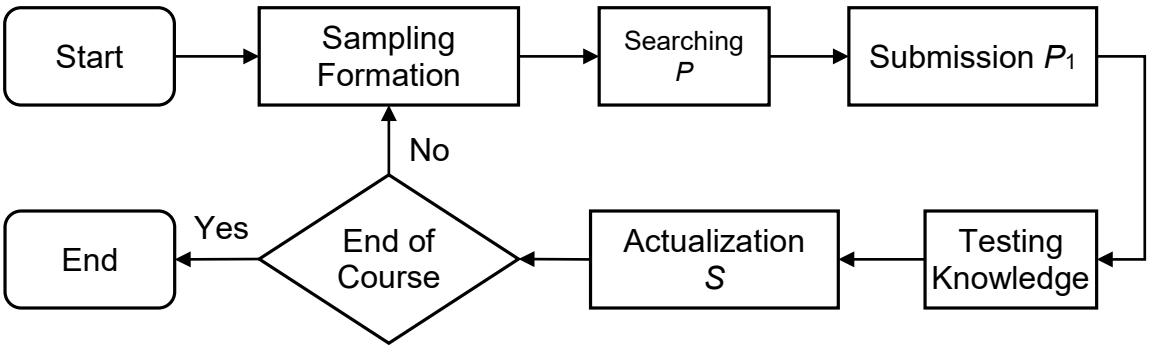

Fig. 2. General block diagram of the adaptive learning algorithm

The algorithm uses two basic concepts. The first is the choice of the optimal learning path P as the solution of the genetic algorithm of the optimization task

$$F(P) = \frac{\sum_i TM_i}{\sum_j R_j} \to \min, \qquad (1)$$

Here TM_i is the time required to study the P_i module from the proposed path, R_j is the predicted level of knowledge of a student in K_j competence at the time of graduation. Thus, the genetic algorithm minimizes the time spent on studying the residual material, while trying to ensure the maximum level of remaining knowledge. The second concept is the use of Ebbinghaus forgetting curves to predict the remaining level of knowledge of the student in each competence of the course. Initially, each student in his model *S* is assigned coefficients of the Ebbinghaus forgetting curve with default values. But during further training, they are corrected, providing unique behavior of the algorithm for each student.

2.3 Toolkit for creating an adaptive course

At present the toolkit is made as a plugin for LMS Moodle (Fig. 3). This toolkit allows the author of an adaptive course [5, 6]:
- to fill the course with modules and competences;
- to link the modules with each other, specifying their input and output competences;
- link the competences with tests that measure the level of knowledge of these competences;
- follow the progress of students, receiving various kinds of analytics.

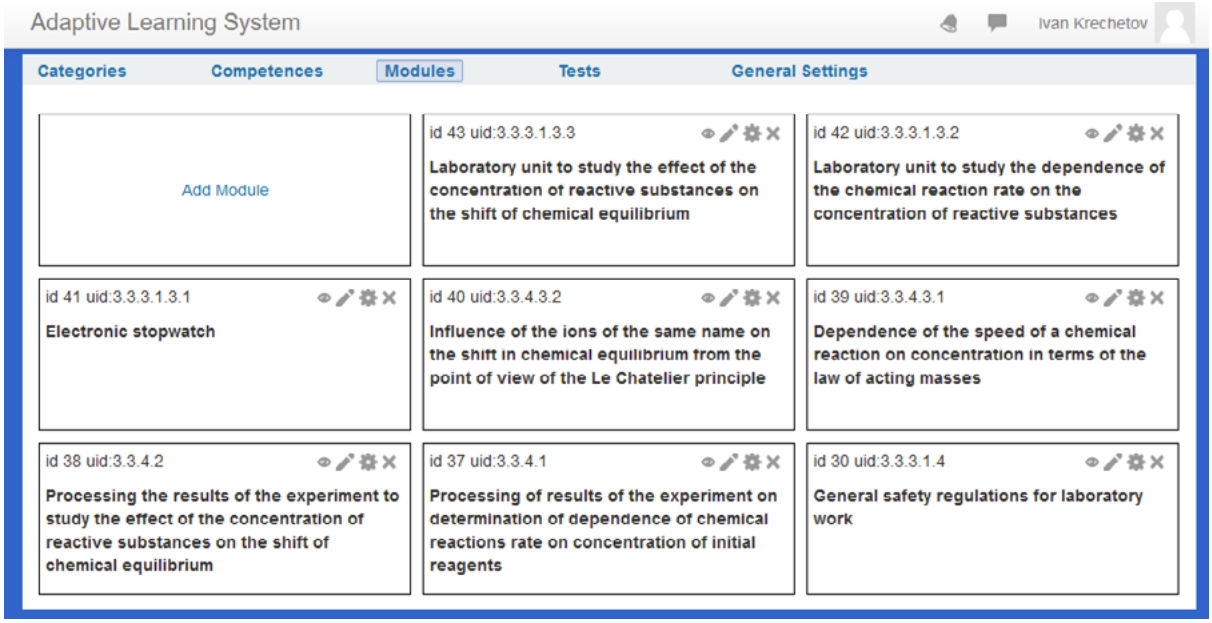

Fig. 3. Adaptive Course Developer Interface

Since adaptive courses are used not only in distance learning but also in face-to-face teaching, it is possible to add competences to the base, for which grades can only be obtained from the teacher. For example, it can be laboratory work – first, the student studies the necessary theory in an electronic adaptive course, performs tests, etc., and then the laboratory work is performed directly at the university and passed before the teacher. Correspondingly, there is a tool for setting the level of knowledge on such competences. But, as mentioned above, their inclusion in the adaptive course is not mandatory, i.e. it can function fully independently.

2.4 Procedure for developing adaptive courses

Thus, according to the proposed methodology, the development of an adaptive course is carried out in the following order:

1. The authors of the course (teachers or methodologists) prepare all necessary materials (description of competencies, modules, tests). For this purpose, a special instruction was developed, which specifies the principles of decomposition of training material into modules and competences, as well as the format of their description.
2. Technical specialists parse the prepared materials and import metadata into the system. Metadata sets the course structure (linking modules, competencies, and tests) and properties of its elements. After that, the layout designer handles the content of the course modules, and the testing specialist handles the layout of the test questions.
3. Technical specialists perform the final assembly and adjustment of the adaptive course, as well as its test run. Its purpose is to make sure that the trajectories offered by the system coincide with the expected trajectories. After that, the test run is performed by the authors of the course. If any deficiencies are detected, technical experts will edit the metadata and course content.

4. A ready-made adaptive course is provided to the trainees. The analytics collected in the course of its operation allows, among other things, to identify defects in course design (for example, too simple or too complex elements of the course).
Therefore, all the necessary tools are now available, as well as a well-tried procedure for creating adaptive training courses. The described methodology has been tested in the process of creating the adaptive course "General Chemistry" for MISIS.

3 RESULTS

3.1 Results of the adaptive course approbation

When teaching the discipline "General Chemistry", the model of blended learning based on "inverted class" technology was used [7, 8]. The traditional structure of "General Chemistry" course includes three types of activities: lectures, practical and laboratory classes. Each type of classroom sessions was supplemented by an adaptive component implemented in an LMS environment.
The effectiveness of the adaptive course can be assessed on the basis of the diagram is shown in Fig. 4. On the ordinate axis, the percentage of students who have successfully coped with the examining activity by certain activity type is given. Test groups were selected from a single stream of the same specialization, taught by one teacher.

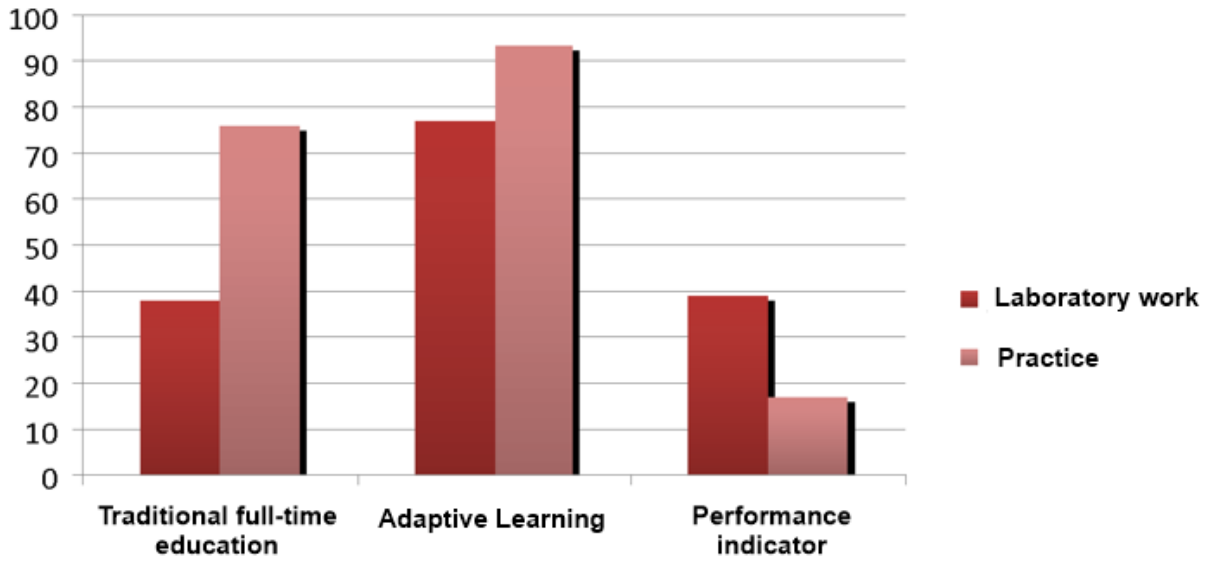

Fig. 4. Approbation results

The chart shows that the performance of students from the experimental group (using adaptive learning) in all types of control activities is significantly higher than students learning the program in the traditional format.
Thus, all the tasks of the project have been completed. The implementation of the created course proved the effectiveness of adaptive learning technology in general and the effectiveness of the developed platform in particular. Therefore, a new

adaptive course in the discipline "Mathematics" for MISIS is already being developed and a number of other courses for different universities are planned to be developed.

3.2 Further development of the platform

The platform is currently being actively developed. Accordingly, the additional functionality described below can be used when developing new adaptive courses. Firstly, there are new possibilities to set up links between modules. The practice has shown that in some cases, the learning path can loop when a student can not pass the exit test after studying the next module, and there are no alternative modules to study at the moment. Therefore, it is possible to establish additional links that describe possible paths for further study. For example, with references to previously studied material: it is possible that it is precisely what a student has poorly learned prevents him or her from progressing further in the course.
For this purpose, new concepts - "prerequisite" and "marker" - have been introduced. Prerequisites to module M are other modules that a student should have studied sometime before (perhaps even within another previous discipline). Initially, they are not placed into the path but appear in it if the student was unable to pass module M. Markers are a more subtle tool. Markers mark individual questions in tests, and it depends on the correctness of the answer to the question whether the module to which the marker points will be included in the further path or not.
Gradation of modules by types has also been added. For example, a diagnostic module allows a student to exclude from the trajectory whole sections of a discipline if the student is already familiar with them.
Secondly, the concept of platform implementation in the form of a cloud solution independent of the specific LMS is being developed. Integration into LMS will be done with the help of LTI or xAPI standards. This will also allow to take into account the student's progress in other disciplines, if it is preserved, for example, in the LRS (Learning Record Store). On the other hand, a student's progress in an adaptive course can be preserved in the LRS, many of which have powerful learning information analytics tools.
Thirdly, the adaptive course developer toolkit is being developed in the way it is not dependent on the LMS Moodle. For example, a trial version of the module and competence editor has been implemented on the Semantic MediaWiki[6] platform.
In general, the author's team has the concept of creating a common interdisciplinary storage of modules and competences. Then it will be easy to include into one discipline topics from other disciplines, as well as take into account the progress of mastering competencies from one discipline to another. In addition, it would allow using modules from other disciplines as preconditions. In this way, an integrated adaptive learning process will be created from the moment students enter the university until the moment they graduate.

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IMPLEMENTING ICT WHEN TEACHING IN HIGHER EDUCATION - A QUESTION OF SUPPORTING TEACHERS' MOTIVATION

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Conference Key Areas*: Interdisciplinary education, E-learning, blended learning, virtual reality & Engineering curriculum design, challenge based education, maker projects, use of professional tools.*

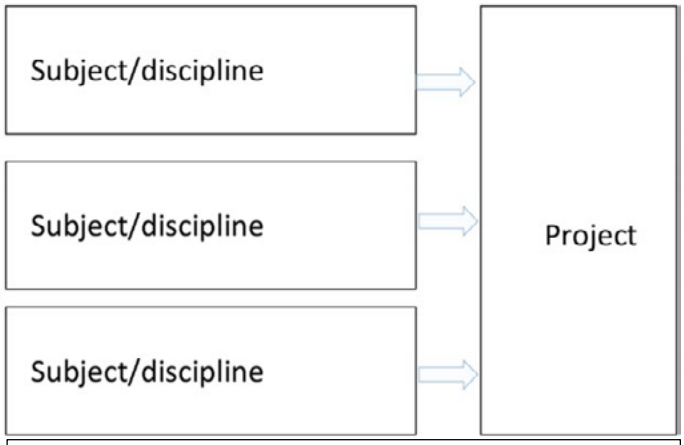
Keywords*: ICT, Integration, Curriculum, Motivation, Change,* Competences, relatedness, autonomy.

ABSTRACT

Information and Communication Technologies (ICT) to support teaching and learning practices at universities has become widely spread through digitalization strategies and to enhance efficiency. It brings new possibilities and challenges and a growing number of studies show how it affects students' learning and motivation [1]. In this paper we will look at how the implementation of ICT affects the conditions under which the teachers work and are motivated for creating motivating teaching. At Aalborg University (AAU), in a research project "Future directions of problem-based learning in a digital age", a subproject is studying how changes, when implementing new ICT, are affecting the pedagogical support of students' learning. The research group have documented the ICT implementation of a bigger change, and in this paper, student surveys and an interview with a teacher will be used to illuminate the challenges and the influences on motivation that teachers experience when trying to integrate courses and projects.

1. INTRODUCTION

Teaching in a Problem Based Learning (PBL) environment as done at Aalborg University (AAU) is for teachers to actively work with and have directions for the pedagogical approach used at the university. At AAU, the pedagogical PBL models cover a variety of problem understandings from rather structured problems to ill-structured and very complex problems [2]. The PBL approach at the university is based on 9 guiding principles which are meant to support a mix of collaboration and project management skills as well as subject specific skills through an integrated structure of course work and project work [3]. A semester in general is structured with three 5 ECTS courses and a 15 ECTS project work. Application of knowledge from the courses to the more in depth work in the large project is crucial for the whole structure of the curriculum. Integration of courses and project is therefore important [3]. Although the PBL-model is a distinctive feature of Aalborg University, the principles have been challenged in recent years. Lack of resources and a change of semester courses to be individual courses with related stand-alone exams has impacted the ability to integrate courses and projects [4]. Students' projects though, are still cornerstones in many curricula and the knowledge from courses still have to support and be included in the projects.



Figur 1. Illustration of semester structure at AAU

However, surveys have shown that both students and teachers have difficulties integrating knowledge from courses into the project work [5],[6]. Many teachers are aware of improving their teaching strategies and have been involved in different forms of new pedagogic approaches as flipped classroom, gaming, new ICT platforms etc.

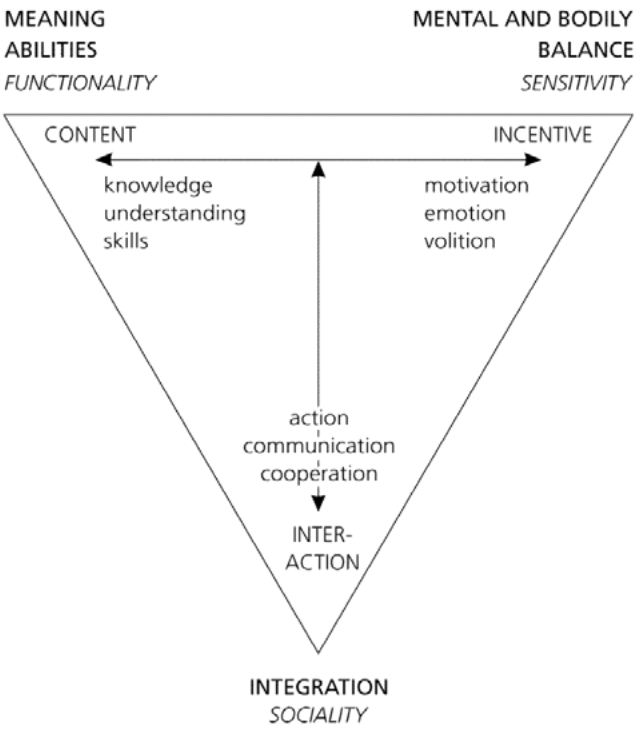
Under the cross-faculty research project "Future directions of problem-based learning in a digital age" (PBL Future) [7], a subproject is studying how changing to an ICT supported teaching approach affect the learning conditions and the PBL support. In a co-creation process [8] between the research group, under the PBL Future project, and teachers at a 4th semester bachelor program in Media Technology, a new ICT based semester structure has been established and run for the first time in spring 2019 and again in spring 2020.

From running the three courses relatively separate and having a semester project running parallel, with a wide framework for students' choice of what to work with and how to integrate things from the courses, a new flipped and integrated semester project was developed. In this case of changing to an ICT supported teaching strategy the flipped learning approach has been used. We have seen that the flipped learning approach can be a great support for more active learning when doing in-class activities, as the flipped learning approach builds on some of the same learning theories as PBL, such as social and active learning theories [9],[10]. Research though show that teachers using the flipped learning approach have to put an extra effort into motivating the students, especially because the approach is relying on ICT based self-study materials that can be difficult for students to get through [11],[5].

Studies at Aalborg University shows that students are highly motivated when doing their project work, but the motivation can be lacking in course-work [6].
Looking at self-determination theory by Ryan and Deci [12], intrinsic motivation is dependent on three basic needs: autonomy, competence development and relatedness. Looking at the AAU PBL model the biggest emphasis on these three basic needs is found in students' project work, where they work in groups with self-defined problems and have time for in-depth studying what they themselves have chosen to engage in. They have autonomy of what to work with, and relatedness to the group, whom they do the project together with. In courses, the study plan is stricter and based on the disciplinary learning objectives of the course subject. This research project running at two full semesters is building on the theory, that integration between project work and coursework will increase the intrinsic motivation with students, as they will be able to draw on the motivation for the project when doing project related work in the courses. Designing the semester structure that support students' motivation while implementing ICT is the rationale behind the initiative done at 4th semester Media Technology. In this paper, we want to put focus on the teachers' motivation and ability to go through such huge changes in their teaching practice which leads to the general research question:
What are the conditions for teachers' motivation when starting ICT based teaching in a PBL environment aiming at integrating courses and projects, and how is the pedagogical approach affected in this transition?

2. THEORETICAL FRAMEWORK

When teachers implement ICT into their teaching strategy the whole practice can be affected. Illeris [13] presents three basic dimensions for planning and analysing learning: *Content, Incentive* and *Interaction*. The teachers of 4th semester had to plan and practice their teaching according to the flipped and integrated semester concept and we will use Illeris' figure to analyse how these basic dimensions are changing and further we will look at how this change affects the teachers and their motivation. As teachers implement new ICT they have to *interact* with a new materiality. In this case teachers have to interact with video, sound, pictures and other flipped learning material, and they are to communicate and cooperate the *content* and *incentive* of their teaching within new digital interaction forms. Teachers have to get skilled within ICT to communicate and create the pedagogical aimed interaction cf. PBL at AAU. By looking into the planning and practice of the 4th semester concept we will be able to see an example of how the ICT implementation affects the basic dimensions of learning. Further we will, by looking at the



Figur 2. Illeris' three dimentions of learning [13 p.118]

implementation of the new ICT based concept, from a teacher perspective, illuminate the effect of the implementation on the teacher's motivation.
Ryan and Deci and the self-determination theory are traditionally only looking at students' motivation, but in a new article 2020, they focus on the teachers' perspective of motivation [12]. Teachers also need motivational support to create motivational teaching for their students. Ryan & Deci indeed point out that the teachers' position today is filled with overwhelming demands from both above (administration and policies) and below (students and parents), which can make it difficult to be a motivating teacher. Teachers have, like their students, the same basic needs for *autonomy, competences* within the content of teaching and *relatedness*, all to support their self motivation, take initiative, be engaged and do adjustments in their teaching [12]. Studies show that motivated teachers make more motivated students [14]. We will bring this perspective of motivation theory into use while looking at the conditions in which teachers of the 4th semester is implementing new ICT while working on integration.

3. CASE STUDY: THE 4TH SEMESTER OF MEDIA TECHNOLOGY

4th semester Media Technology is an Engineering Education based on mathematics, technology and humanistic disciplines. Almost all teachers are educated within engineering and science, but are interested in the pedagogical aspects, especially because not all students have an interest or find themselves motivated in subjects as math or programming [15]. Five teachers are running the three courses listed as 5 ECTS each: Audio Processing (AP), Design and Analysis of Experiments (DAE) and Physical Interface Design (PID), and the semester project is 15 ECTS with the theme Sound Computing and Sensor Technology [16]. All three courses have been flipped simultaneously from semester start in 2019. One of the courses had undergone the transition towards a flipped approach several years prior. According to the teacher, these years had included many mistakes and experiences, leading the course to its current format, including its didactic and pedagogical strategy. The AP course that we will look further into in this paper has one main course teacher who has not been working with the flipped learning approach before this project started. The AP course has not been well liked by the students.

4. METHODOLOGY CONSIDERATIONS

The authors of this paper were following the 'experiment' on the 4th semester, and collected data throughout the entire semesters from 2018 - 2020. Different kind of data has been collected, but in this paper focusing on the teachers' motivation only three forms of data will be used to illuminate the effect of ICT on teachers' motivation for changing teaching practice. A student survey from October 2019, evaluating the first run of the flipped and integrated semester concept, will be used to look at how the teachers were affected by the feedback and recommendations to change their teaching approach in spring 2020. These data give insight in the feedback that the teachers had to adjust their teaching according to. In this evaluating survey 2019, there were 59 students enrolled at the 4th semester. 40 out of the 59 students answered the survey and we will in this paper draw on some of the overall evaluation outcomes [17]. Further we will use data from semi-structured interviews [18] done in February 2020 with 4th semester teachers. The focus of the interviews was as follows: Experiences done in 2019 and the planning process of the 2020 semester, outline of the 2020 concept and how the research group have supported the development. Finally we have used observations from in-class sessions and the

learning platform Moodle. As many factors play a role when looking at the effect of implementing ICT in a teaching practice, we have chosen to look at only one of the courses as a case study for this paper [19] and thereby go deeper into the complexity of handling the transformation to the new flipped and integrated semester concept. The AP course were chosen and a one hour interview with the main teacher of the course has been fully transcribed and anonymized.
From the beginning of the process it was decided that the teachers and researchers would develop the new semester in cooperation. During the process our roles have shifted between co-creation, passive participation, active participation and complete participation [20]. The longitudinal studies meant that it has been an imperative to reflect the different data as well as give immediate feedback to the teachers. This feedback system has been of great interest and well-liked by the teachers, who are not used to much feedback on their work, but we are aware that it might also have served as an element of pressuring the teachers' work.

5. MOVEMENTS WITHIN THE LEARNING DIMENSIONS WHEN IMPLEMENTING ICT

In summer 2019, the first run of the flipped and integrated semester was done, and expectedly there was room for improvements. Student surveys evaluating the semester were very informative and in general, students' feedback gave a lot of good advice as well as concrete suggestions for changes [17]. Teachers were given the feedback and it outlined problems with especially the integration between courses and project work. Feedback from students showed that a lot of the course content was not applicable to the projects and one reason for that was that the ICT were not aligned and thereby could not 'talk together'. Therefore, the technological platforms used at AP had to be changed entirely for the spring 2020. The teacher explains:

> "We changed the entire technical platform. And that didn't come just like out of the blue to do that. So, we spent a lot of time getting the knowledge, getting the first parts. So, I don't feel too shy to say that I used part of my summer holiday for that, but I think it pays off. So, it's investment to the future." (Teacher A, 17.30)

The AP teacher had to be qualified within the new ICT that he now had to use and a lot of resources had to be put in, getting qualified and knowing how to interact with a new ICT. Further we see that these tasks did not end with the planning process. The teacher had to be very agile and find new technological solutions handling problems that arose on the way. The teacher had to, after semester start, move the entire platform to a cloud solution to make sure all students, independent of their user hardware, could participate in the lectures. Cross-cutting ICT became essential for integration and for relating in a similar way to the teaching content. Students also outlined other problems concerning the interaction with ICT and recommended extensive change. The AP teacher reflects on the feedback saying:

> "One of the feedbacks [from the students] was, I still remember it, it's a good way of putting that […] Having a third-party guy's videos, coding on the computer is not too relevant for us and not motivating us" (Teacher A, 36.04).

This third-party guy's video material affected the relatedness between student and teacher and affected the students' ability to be motivated. Teaching in a PBL environment requires a social and active learning approach and the relatedness between teacher and student is very important for the facilitation of PBL supported teaching. The AP teacher chose to change his entire teaching content to plan for a

better relation with the students and thereby a better possibility for motivation in the teaching practice.
Student evaluations from 2019 formed a range of pressure for improving teaching practice. Beside extensive changes in the teaching content and change in ICT to enhance better integration, the students' feedback also placed a pressure on the teachers' internal and administrative communication. Students asked for a substantial coordination effort, including how to align courses, semester projects and exams better. Constructing a tighter scope-limiting frame for the semester projects became necessary for creating integration points across the courses.
Communication and integration found its peace in some common touch points, e.g. joint supervision, midterm presentation and joint workshop week. The AP teacher describes the communication like this:

> "We spend more time this year of coordinating the initial plans. But now I think we're executing that separately, with some kind of touch points about the joint supervision. And some touch points in the mutual events. And I think this is much better, because it kind of concentrates the collaboration time to specific points that you don't feel all the time, that you should coordinate." (Teacher A, 23.02).

Creating these touch points for when and how to work on integration was planned in advance, meaning that regular communication between the teachers could be less. The integration initiative is thereby focused on those touchpoints and less holistic. The AP teacher explains how he needs to create a focus in all of these new and changing ways of doing his teaching practice:

> "So we can interleave the focus maybe, but I think nobody should expect that all the courses are learned well and the projects are integrated at the same time. So right now, I'm openly focusing on the course. I invested a lot in the course and other courses as well [not on Media Technology]. If we can share the [ICT] platform next year we can look at better project integration. So that is my personal working, but I don't give up so it's not that we don't do it." (Teacher A, 53.34)

Many things had to be changed on the AP teacher's course just to get the ICT working and find technology to make integration possible across courses and semester project. He has had to be very agile reacting on all of the student feedback and adjusting his teaching on the go, and he has now had to draw a line for how much to embrace. He don't give up on the integration, but have had to choose a focus and integration can be looked at again when some of the ICT related teaching concerns are more stabilized.

6. TEACHERS' MOTIVATION

Ryan and Deci´s perspective on the teachers' basic needs can be relevant for looking at the effect of implementing new ICT into a teaching practice. As the teacher at the AP course implement the new ICT and is working on creating a more integrated structure across the full semester, a lot of feedback for improvements have affected the teacher. Because the research group have been involved, a lot more feedback than usual have been given to the teachers and huge changes have been made on the basis of this. The AP teacher has had to qualify within new ICT competences, and he has had to change the ICT platform to create better conditions for integration and relating to the students. The teacher's basic need of feeling competent and being related to the students has been challenged because of the ICT mediated interaction. Teachers are in general responsible for the courses they

are teaching, and they have the autonomy within this framework, but integration puts new demands upon the teachers autonomy. They have been challenged to cooperate and adjust their course so it is aligned with the other courses and the semester project, this by again changing ICT platform to an ICT that is cross-cutting and planning the content to fit common touch points across the semester. What before was one or two teachers' own domain in a course where they had the full autonomy, is now affected by teachers from the whole semester. Further teachers' feeling of relatedness have expanded from only concerning the students to in much higher degree also concerning the other teachers at the semester. Disciplinary and interdisciplinary collaboration is needed, and studies show that the communication is getting more complex all the more interdisciplinary the task is [21]. Settling on some joint touch points is a way of framing the communication to a certain degree making it easier to handle, but also limiting the actual integration. If the teachers don't communicate regularly they don't have the ability to adjust in an agile manner to what is happening in the actual teaching practice. As many changes have been necessary, handling the planning of students' learning abilities, because of the implementation of new ICT, teachers might run to the wall of lacking motivation. A lot of initiatives have been done both concerning adjusting the teaching to the ICT and working on the integration, but the AP teacher must conclude that not all can be done at the same time. Handling integration tasks while also working with ICT supported teaching is challenging to the teachers and their motivation because it pressures the teachers on all basic needs for being motivated.

7. CONCLUSION

Implementing ICT in a PBL environment and also supporting an integrated curriculum has shown to imply a lot of pressure on the teachers to make big adjustments in the teaching design, and it have affected their motivation. We conclude in relation to the three motivational factors: Competence development, relatedness and autonomy.

Competence development during the process of implementing ICT and a new teaching practice has been challenging. It is not only the technical issues but also developing new materials as well as defining and testing a new teaching and learning design that fits students' developmental process.

Being related to students during a change, learning and teaching process is demanding as students have to be 'on the same page' meaning that teachers have to follow students' developments to be able to communicate with the students. The importance of establishing a good communication is essential.

The teachers' autonomy is challenging even. There is still freedom and responsibility for the single teacher, but they have to recognize the bigger picture of integrating courses and project work and this pressures the teachers' autonomy.

A lot of pedagogical tasks working with integration have been placed in a defined frame to reduce the complexity of cooperation and communication among the teachers, but this also decreases the level of integration across the full semester.

The ICT might at first increase the need for confined and autonomous teaching practises as a reaction to all of the changes needed when implementing new ICT in a teaching practice, but the AP teacher still have the motivation to work on improving the integration when the ICT changes don't take up so much time.

It shows important when working with implementing ICT, while also aming for an integrated curriculum structure, to make room for the teachers' development and adjustment of the practice. Both to ensure that the teachers are not pressured too

much and loose motivation in the process, and to ensure room for adjusting the teaching design and thereby ensuring the quality of the teaching.

8. ACKNOWLEDGEMENT

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MATHEMATICS SELF-EFFICACY, LEARNING APPROACHES, ACADEMIC PERFORMANCE IN THE LIGHT OF THE NUMBER OF FAILED ATTEMPTS

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Conference Key Areas: *Mathematics in the engineering curriculum*
Keywords: *mathematics self-efficacy, learning approaches, achievement, number of failed attempts*

ABSTRACT

Mathematics is a language for expressing physical, chemical and engineering laws nevertheless engineering students often perform poorly in mathematics. Studying can be influenced by several different social, cognitive and non-cognitive factors which all can have an impact on students' academic performance. Many researches revealed positive effects of mathematics self-efficacy on mathematics achievement. Similar results can be found among learning approaches, students using deep-approach achieve better results. It is legitimate to question whether there is a relationship between self-efficacy and learning approaches.

My research focused on the interrelationship between two aspects of mathematics self-efficacy (mastery experience, physiological state), learning approaches (deep strategy, deep motive, surface strategy, surface motive) and achievement. This research also examined the variance of self-efficacy, learning approaches and achievement in relation to the number of failed attempts.

306 undergraduate engineering students at a Hungarian university took part in the study. To examine the above mentioned question the study employed quantitative approach and data were collected using two questionnaires during the semester. The self-efficacy scale was adapted from a variety of sources and was modified to local conditions. To measure learning approaches the Revised Two Factor Study Process Questionnaire was rephrased to the domain of mathematics and to the local conditons. The data were analysed quantitatively using descriptive statistics, bivariate correlation, partial correlation, and regression analysis. The results show that self-efficacy, learning approaches and academic achievement were strongly correlated with each other. Students who have higher level self-efficacy use deep strategy in learning and have deep motives, while students classified as low in self-efficacy adopted surface learning approaches. A new variable was introduced which has not been investigated yet in other researches: the number of failed attempts. A significant correlation between the mentioned variables and the number of attempts was identified.

My results demonstrate the importance of such kind of learning environment which fosters self-efficacy and deep learning approach.

1 INTRODUCTION

Numerous studies investigate factors that impact graduation and transfer rates in higher education but most of them focus on demographic factors. Amelink et al. [1] examined graduation from an other perspective and they found that college students who experience high self-efficacy are more likely to graduate and transfer. Cohen et al. [2] identified other factors as well, they suggest that rate of science and mathematics course completion, science and mathematics course enrollment, and required mathatics remediation coursework were significant predictors of graduation and transfer, namely taking mathematics and science coursework is positively related to successful outcome.

Mathematics is very important in the study of engineering but many students perform poorly in mathematics. There are many factors which can influence mathematics achievement: based on Marzano [3] meta-analysis 80 % of the variance in achievement could be accounted for by student effects, 13 % by teacher effects and 7 % by school effects [4]. This provides a strong reason for a deeper examination of student-related intraphysical factors including self-efficacy and learning approaches (deep strategy, deep motive, surface strategy, surface motive) and an other student-related factor – which has not been yet researched – such as the number of failed attempts.

2 THEORETICAL BACKGROUND

2.1 Self-efficacy

The findings of Stankov et al. showed that a group of self-beliefs constructs, in particular, self-efficacy in PISA, confidence in TIMSS, and educational aspiration, in both TIMSS and PISA, were the best predictors of individual-level student achievement in mathematics [5]. The concept of self-efficacy was originally introduced by Albert Bandura as part of the social cognitive theory [6]. Self-efficacy can be examined in all areas of life but in this study education is in focus. Academic self-efficacy refers to students' beliefs about themselves and their academic competence influences their academic performance and level of engagement in learning and help determine what they do with the knowledge and skills they possess. Bandura [7] hypothesized that self-efficacy produces different effects through four major sources: mastery experience, vicarious experience, social persuasions, physiological states. The most powerful source is mastery experience that students gain during a learning process as they interpret their academic competence when they accomplish an academic task. Personal experiences with success and failure form students' perception about their ability to complete a task. The second source appears as vicarious experience. Observing others' experiences can empower students to believe in their own ability and success. The third source of self-efficacy comes from social persuasions, through feedback from peers, teachers, family. Finally, the fourth source is based on the physiological states such as stress, anxiety, fatigue and mood. These sources obviously contribute to students' decisions, how much effort they put in studying. Although all four sources examine one part of self-efficacy, but not with the

same weight. Hutchison et al. [8] implemented a qualitative measure of first year engineering students' self-efficacy beliefs and their results presented the majority of mastery experiences.
Previous reseaches report the variance of self-efficacy in the context of gender, grade level, age, achievement, different domains, migration background. However, self-efficacy is not independent from other intrapsychological concepts, researches investigate its interrelationship with e.g. goal orientation, self beliefs, confidence and learning approaches.

2.2 Learning approaches

Learning approaches has been investigated since 1970's, when Marton and Saljo, two phenomenological psychologists, postulated surface and deep level learning processing. This dichotomized view was extended by Biggs [9] who proposed surface, deep and achieving approach to learning all with two components, motive (why the student wants to approach the task) and strategy (how the student approaches it). A number of studies showed that a two factor model with deep and surface approaches has the best fit, instead of the three factor model. Table 1 provides an overview of the definition of learning approaches and its components.

Table 1. Learning approaches

Learning approach	Learning Motive	Learning Strategy
Surface Approach	meet requirements minimally: balance between working too hard and failing	reproductive: reproduce through rote learning
Deep Approach	intrinsic interest: develop competence in particular academic subjects	meaningful: read widely, searching for analogies, interrelate with previous relevant knowledge

The European Society for Engineering Education (SEFI) published A Framework for Mathematics Curricula in Engineering Education which aims to provide guidelines for universities and educators in the topic of general mathematical competencies for engineers, content-related competencies, knowledge and skills, teaching and learning environments, and assessment. A chapter is dedicated to attitudes, in which we can read about learning approaches and a possible path to a deep learning strategy [10]. Before any educational intervention, a state measurement is needed to set clear goals.

3 OBJECTIVE

The purpose of the present study is to reveal the relationship between students' mathematics self-efficacy, learning approaches and academic achievement in a new context by introducing a new variable (the number of failed attempts). Therefore, the present study aimed to answer the following questions:

1. What is the preferred learning approach toward mathematics of engineering students taking the course Mathematics 1 or Mathematics 2 at Széchenyi István University?
2. Is there a significant interrelationship among mathematics self-efficacy, learning approaches and academic achievement?
3. How the number of failed attempts relates to the listed variables?

4 METHODOLOGY

4.1 Participants

This study was part of a larger multiphase research which examined students' learning characteristics and teaching method preferences in a Hungarian technical university. The participants of this study were 306 engineering students who participated in Mathematics 1 or Mathematics 2 courses in the same semester. Mathematics 1 and Mathematics 2 are successive courses in the first year at Bachelor level, and all students have to attend both courses. 36% of students have repeated the course at least once. Most of the students were mechanical engineering students (61%), but there were vehicle engineers, logistic engineers, computer science engineers, architects, and environmental engineers. Students completed two questionnaires right before writing the first mid-term test in October 2019 and second mid-term test in November 2019.

4.2 Survey instruments

The data collection instruments that were used: mathematics self-efficacy scale, study process questionnaire, university records.

2.2.1 Mathematics self-efficacy scale

The mathematics self-efficacy scale was a 5-point Likert type mathematics specific scale. The scale was comprised of 15 items which were adapted from a variety of sources and were modified to local conditions. Since mastery experience is the strongest and consistent predictor of self-efficacy [11], 11 items assessed this source of self-efficacy. Moreover 4 items aimed to measure the emotional and physiological states of students. One item in matery experience and each of the physiological state items were reverse worded. The maximum possible score for self-efficacy was 75 (55 for mastery experience, 20 for physiological state) and the minimum score was 15 (11 for mastery experience, 4 for physiological state). The reliability coefficient (internal consistency) of Cronbach alpha was .89 for mastery experience and .77 for physiological state.

2.2.2 Study process questionnaire

The Revised Two Factor Study Process Questionnaire was adapted to the local conditons. The original 5-point Likert type questionnaire consists of 20 items. It measures two approaches: deep and surface approaches. Both approaches contain two subscales: motive and strategy. Each subscales (deep motive, deep

strategy, surface motive, surface strategy) have 5 items. These statements were rephrased based on local mathematics education for engineers. Some examples for rephrasing:

"I find that studying mathematics can be just as exciting as other engineering subjects." (Original sentence was: I find that studying (academic) topics can at times be as exciting as a good novel or movie.)

"I spend a lot of my free time finding out more about the mathematics background of engineering classes." (Original sentence was: I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.)

Cronbach's alpha coefficient was used to examine internal consistency among items, .873 for deep approach, and .737 for surface approach.

2.2.3 University records

In this study academic achievement was measured by the sum of the two mid-term tests scores. The maximum possible score for each mid-term test was 12, consequently the total maximum score was 24.
The number of attempts means how many times a student registered for the same course because he failed to pass.

4.3 Method of Data Analysis

The data were analysed quantitatively using descriptive statistics involving mean and standard deviation, frequency distribution and percentage, bivariate correlation, partial correlation, and regression analysis by using the Statistical Package of Social Sciences (SPSS version 26). Mean and standard deviation were used to see the variation among the variables. Correlation revealed the interrelationship between self-efficacy, learning approaches and academic achievement. Partial correlation was employed to see the relationship between the listed variables while controlling the effect of the number of attempts. Regression was performed to see the independent contributions of the predictor variables to the criterion variable (academic achievement).

5 RESULTS

The purpose of the present study was to examine the interrelationship between students' mathematics self-efficacy, learning approaches and academic achievement, and their relationship to the number of failed attempts.

5.1 Preferred learning approach

The data in Table 2 below present descriptive statistics of variables.

Table 2. Descriptive statistics of variables

	N	Minimum	Maximum	Mean	Std. Deviation
Deep Approach	260	10	50	30.32	8.038
Surface Approach	260	10	44	26.42	6.649
Mastery experience	256	13	55	37.94	8.563
Physiological state	256	4	20	9.63	4.009
Academic achievement	306	0	24	9.15	6.000
Valid N (listwise)	219				

Table 2 indicates that the most preferred learning approach was deep approach (M=30.32). The plot in Figure 1 gives information about that most students belong to a group with high scores in deep approach and moderate scores in surface approach.

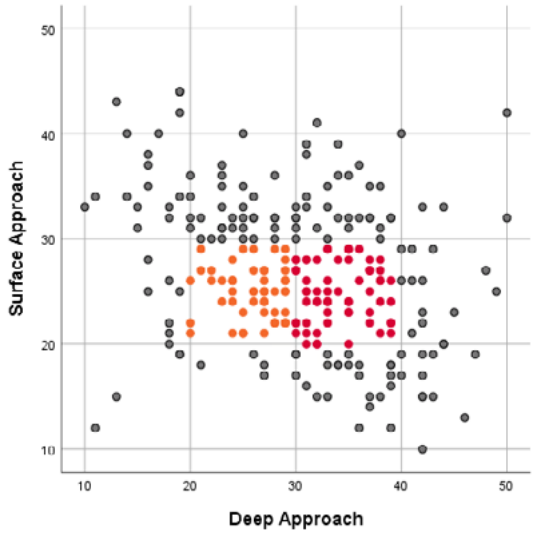


Fig. 1. Scatter Plot of Study Approaches

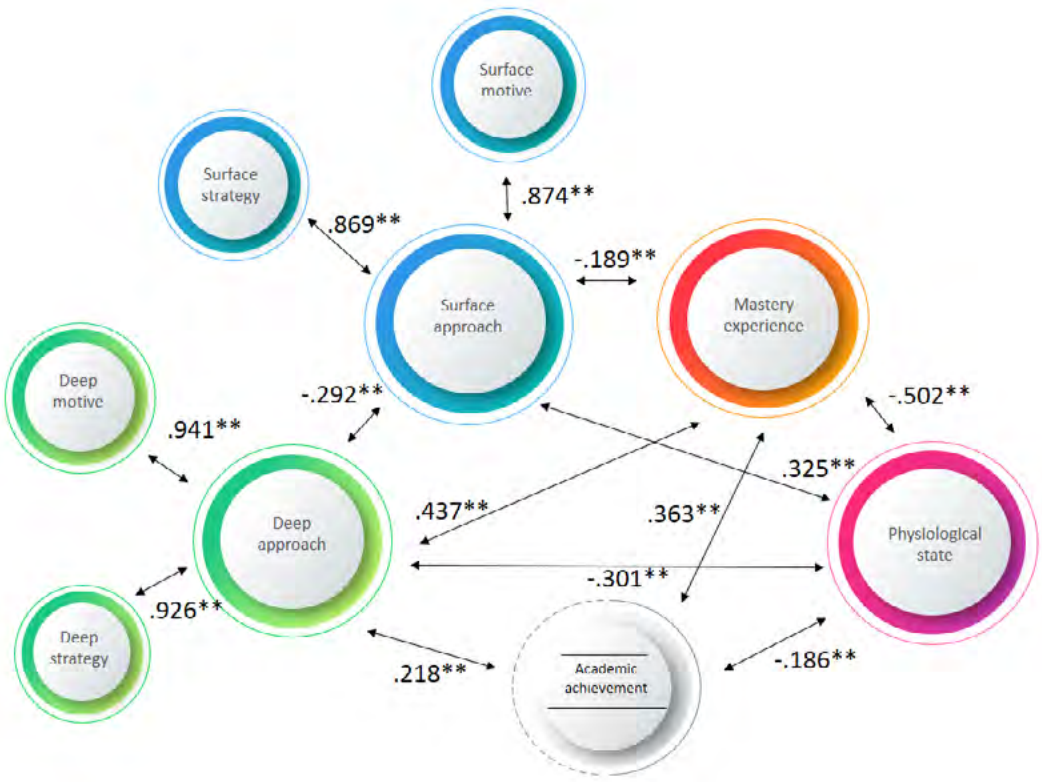
More detailed analysis was conducted with cross tabulation. The numerical distribution in Table 3 supports the above mentioned results. Most students are classified as having moderate to high deep learning approach and moderate surface approach (43,84%).

Table 3. Cross Tabulation of Deep and Surface Learning Approaches Scores

		Deep Approach Scores				
		10-19 (low)	20-29 (moderate)	30-39 (high)	40-50 (very high)	Total
Surface Approach Scores	10-19 (low)	4	4	23	11	42
	20-29 (moderate)	7	52	62	14	135
	30-39 (high)	11	30	29	3	73
	40-50 (very high)	6	1	1	2	10
	Total	28	87	115	30	260

5.2 Interrelationship among mathematics self-efficacy, learning approaches and academic achievement

To reveal the interrelationship between the variables an analysis of the correlation coefficients was used. Figure 2 presents the bivariate correlations of mathematics self-efficacy (mastery experience, physiological state), learning approaches (deep and surface approach with the subscales), and academic achievement. There was statistically significant interrelationship between all examined variables except for surface approach where no significant correlation with achievement was observed.



** Correlation is significant at the 0.01 level (2-tailed).

Fig. 2. Correlation among variables

A significant predicative correlation of deep approach, mastery experience and physiological state have been recorded on academic achievement. The deep learning approach explains only 4,7 %, the physiological state explains 3,5 %, while mastery experience explains 13% of the variability of academic achievement. This means that the more deeply students understand the material, the better their achievement is. As well as the more positively students evaluate the level of their acquired knowledge, skills and competences, the higher their academic achievement is. Furthermore, the more stressful a course is for students, the lower their academic achievement is. Moreover the reverse causality effects also work. The better students perform, the more students are motivated intrinsically/ the better students believe in their own abilities/ the less anxiety they experience. In summary mastery experience and deep approach have positive effects on later achievement and achievement is a source of

later mastery experience and deep approach. Furthermore physiological state has negative effects on later achievement and achievement is a source of later physiological state.

5.3 A new variable: the number of failed attempts

Several possible variables can influence the relationship between self-efficacy and achievement. Possible mediating or moderating variables can include but not limited to students' homework behaviour, motivation, engagement, perceived difficulty of the domain, effort regulation, goal orientation, personality, past performance, self-regulatory learning strategies, parental support, emotional intelligence, time spent on task.

Numerous researches examine the change of self-efficacy over time with longitudinal and cross-sectional sampling. Time appears in these researches as grade level but time can appear in other context as well such as how many semesters a student needs to accomplish a course. Since mathematics courses in higher education have a high failure rate, repetition of the subject may change the student's perception of their own competencies and may even lead to other learning strategies for success. These led us to investigate the relationship between self-efficacy, learning approaches and the number of failed attempts. There is a lack of research which would reveal the effect of the number of attempts. Table 5 presents the bivariate correlations of mathematics self-efficacy (mastery experience, physiological state), learning approaches (deep and surface), academic achievement with the number of attempts. Data show that there is a significant correlation between all variables which show that the number of attempts is a crucial variable. It should be emphasized that there is a negative correlation between mastery experience and the number of attempts, deep learning approach and the number of attempts, as well as achievement and the number of attempts.

In other words, the more times students fail the course the less they feel they have mastery experience, and the higher the level of arousal they have. Moreover, the more times students fail the course the less they use a deep approach to learning, and the more they use a surface approach. Furthermore, the number of attempts has negative impact on achievement.

Table 5. Correlation matrix among variables

Correlations

	Mastery experience	Physiological state	Deep Approach	Surface Approach	Achievement
Number of attempts	-.285**	.211**	-.311**	.132*	-.138*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

If we want a pure measure of the interrelationship between self-efficacy, learning approaches and academic achievement we need to take account of the influence of

the number of attempts. In this case, the results of partial correlations show that there is no significant correlation between any of the variables. Consequently there is no significant relationship between self-efficacy, learning approaches and academic achievement controlling the number of attempts.

5.4 Limitations

In this sample, there are students who failed several times in mathematics or in other subjects than it is allowed, so they had to finish their university studies. However, the following year they were able to reapply to the university and continue their studies. In these cases, we do not have information about that how many times they have failed in mathematics before.

6 SUMMARY

The present study reveals that the deep learning approach was dominant among engineering students which supports the findings of research by Hussin et al. [12]. This result suggests that engineering students are aware that to understand a mathematical concept deeply contributes to their academic success and professional life.

Significant correlation was found between all examined variables except between surface approach and academic achievement. Our findings corfirm the conclusions of research performed by Veresová et al. [13].

The hypothesis that academic self-efficacy influences academic achievement was confirmed by numerous other researchers [14]. In our case mastery experience was the strongest predictor of achievement.

Our research is a niche in the context of examining the relationship between the number of attempts and learning approaches and self-efficacy. There has been a significant correlation between the mentioned variables. These results confirmed that the number of attempts is a significant variable, which can affect students' self-efficacy, learning approaches and achievement through persistence, desperation, coping strategy and self-confidence as the number of attempts increases.

Failing mathematics courses can prevent students from advancing in their other university courses and may impact their experiences about university, about their learning ability and negatively change their attitude toward learning. Mathematics courses appear as stepping-stones to understand the background of other sciences and to seek deeper in the field of engineering. Academic self-efficacy and learning aprroaches have been identified as crucial concepts when considering success and drop-out in higher education among underrepresented groups in STEM fields. The above discussed results capture a state in which educators have to intervene actively. Several "what to do" and "what to say" strategies for improving self-efficacy and motivation are listed in Margolis and McCabe's article [15] in order to help struggling students develop a more positive attitude. Problem-based learning seems to be a possible solution to enhance active learning and studies show that PBL enhances deep learning through discussing professionally relevant problems [16]. The authors of A Framework for Mathematics Curricula in Engineering Education propose that

mathematics should be tought as an integrated subject, and as an applied science because real-life problems can enhance students' deep learning approach [10]. The continuation of this research may focus on the success of the application of the above mentioned strategies. It is our responsibility to set our students on a more productive and satisfying life path.

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DOES A MANDATORY BUT NON-BINDING TEST FOR ASPIRING STUDENTS IMPACT THE DIVERSITY IN AN ENGINEERING BACHELOR?

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Conference Key Areas: *Diversity and inclusiveness*
Keywords: *admission, gender, diversity, engineering, entrance test*

ABSTRACT

Flanders, the Dutch-speaking part of Belgium, has a very open access to higher education. As a result universities have to accept any student with a secondary education diploma into the engineering bachelor, even if the secondary education program does not provide the required knowledge and competencies. To ensure that aspiring students are aware of the required level of mathematical problem solving skills, the universities are since 2013 organizing a non-mandatory and non-binding positioning test in the summer prior to entering higher education. In 2017, the Flemish government decided to make participation to a positioning test mandatory for aspiring engineering students from 2018 on. This mandatory participation could form an additional hurdle for aspiring students, which might impact students of minority groups. This is a concern as female students, pioneering students, and socio-economically challenged students are underrepresented in Flanders' engineering education, while industry still requires more engineers.
This paper is the first to study the impact on the diversity within the engineering program of the mandatory participation to the positioning test mandatory. This paper takes a quantitative yet descriptive approach and looks at the student population regarding gender, socio-economic status, pioneering status, and disability. The first results indicate that the extra hurdle of mandatory participation attracts more students and does not threaten the diversity in engineering bachelors. Furthermore, the mandatory participation to the positioning test did not affect the already better performance of female compared to male students, and reduced the performance gap for pioneering and learning-disabled students.

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1 INTRODUCTION

1.1 Gender and diversity in Engineering Bachelors

News regarding the need for engineers in our high-tech society is omnipresent. As no talent should be wasted in engineering education and as diversity can strengthen engineering education and practice, it is important to look at minority groups. Lent et al. present a social cognitive career development model for understanding three intricately linked aspects of career development: (a) the formation and elaboration of career-relevant interests, (b) selection of academic and career choice options, and (c) performance and persistence in educational and occupational pursuits [1]. The model shows that both personal, contextual, and experiential factors influence the career choice [1]. This paper focuses on female students, students with socio-economic challenges, pioneering students (students whose parents do not have a higher education degree), and students with disabilities. Gender and disability are included among the personal characteristics in Lent's model, while socio-economic status and pioneering status are included among the contextual characteristics. Female students are underrepresented in engineering studies in Europe as shown, among many, by the Attract project [2]. Interviews with engineering professors showed that, despite the underrepresentation of women, policies related to underrepresentation in undergraduate engineering programs are marginalized [3]. Blickenstaff [4] distinguishes six domains within the broad range of explanations in literature regarding the underrepresentation women in STEM: biological, lack of academic preparation, prior attitude, absence of role models, irrelevance of curricula for women, pedagogy tailored for men, chilly climate, cultural pressure for traditional role models, and an inherent masculine worldview inside science. He stresses the responsibility of all actors in the engineering education pipeline, and provides particular recommendations to reform STEM education [4]. Brainard & Carlin [5] found that a significant drop in academic self-confidence during their freshman year is often-occurring reason for female students to leave STEM programs. A Swedish study [6] showed that a competitive environment of STEM studies, the "chilly climate" female students perceive, and the stress they experience during studies can make them less confident in their STEM abilities and can increase the potential for dropping out. Beside gender. DeWitt et al. [7] found that ethnicity and cultural capital influence students' attitudes, experience, and participation of science in school and out of school. While less literature and data is available on the position of students with disabilities in engineering education, the Attract project [2] showed that, as for socio-economic factors, the proportion of students with disabilities in STEM faculties is lower in comparison to other faculties.

1.2 Admission and gender & diversity

Admission, and testing being often part of this, can be a potentially important, hurdle for aspiring engineering students. Within the social cognitive career development model, admission tests relate to both experiential and contextual factors [1]. High-stakes testing during admission have been shown to suffer from a gender and

diversity gap. This gap has been hypothesized to be wider in domains where a “fixed ability” (e.g. believing that success requires innate talent or natural genius) mindset was more common [8]. Even more, high-stake entrance tests strengthen the competitive atmosphere, which has been shown to be discouraging for female students [6]. The impact of gender on high stakes test score is complex. Casey et al. [10] for instance showed that spatial abilities and math self-confidence indirectly mediated relationship between gender and the high stakes test score (SAT in their study). Interestingly, using secondary school grades as a basis for admission has shown to introduce a bias in favour of women, while the reverse is true for standardized test scores [9]. Gender bias in the admission process can therefore strongly be influenced by the admission criteria [11]. Therefore bias can also be mitigated by adapting these admission criteria [11].

1.3 Context

Access to higher education in Flanders, the Dutch-speaking region in Belgium, is open: if students have a diploma of secondary education or a (foreign) diploma declared equivalent, they are directly admitted to any professional or academic bachelor’s programme, with an exception for medicine, dentistry, and some programs in performing arts. Even for programs such as the Bachelor of Engineering Science, which rely on a strong mathematical prior skills, no formal requirements regarding students’ prior education or mathematical proficiency can be formulated by the university. Together with the open-admission policy, low tuition fees (around 1000 euro for one academic year) are seen as important for the accessibility of higher education. On the negative side however, it results in a heterogeneous population regarding prior knowledge and skills, challenging teaching and guidance of especially first-year students. Students who do not have the required prior skills or motivation still enter the program, which contributes to a rather high drop-out rate of around 40% in the Bachelor of Engineering Science. Historically, the Engineering Science programs in Flanders did not have such an open-admission policy: until 2004 a multi-topic entrance exam existed for Engineering Science in Flanders, which assessed the mathematical prior skills of aspiring students. This entrance exam was believed to contribute to the high level of mathematics education in secondary schools, as it acted as a beacon for aspiring students and the schools of secondary education, and contributed to an international high reputation of the Flemish mathematics secondary school education [12]. After the abolishment of the entrance exam in 2014, a steady decrease of the first-year success rate was observed: from around 70% it dropped to less than 50%. In order to address the decreasing success rate all three Flemish universities with an Engineering Science bachelors in 2013 jointly installed a positioning test, which provides aspiring students with feedback on their mathematical skills and allows to compare their skill level with the required one [13]. The positioning test, called `ijkingstoets’ (www.ijkingstoets.be), is administered in the summer before entering higher education in two separate session. The multiple-choice test has around 30 mathematical problem solving, which the aspiring students solve in maximum four hours. The feedback aims at encouraging students

who succeed to subscribe in the program, stimulating students who are less successful to better prepare themselves by entering a remediation trajectory, and triggering reflection around the study choice for students who clearly lack the required skills. The score on the positioning test was found to be predictive for student success [14]. Furthermore it was shown that while female students on average score lower on the positioning test, their decision to enrol or not does not differ from male students [15]. The inclusive approach of the positioning test, by granting all participants more than enough time for completing the test, seemed to be successful as students with learning disabilities did not obtain lower scores on average [15]. After a decision of the Flemish Parliament, the positioning test became a "mandatory, non-binding entrance exam" in 2018, indicating that *participation* to the positioning test is mandatory for all aspiring students wanting to subscribe to the Bachelor Engineering Science, but that entrance to the program does not depend on the actual score on the test (non-binding). Each university has a committee who can grant exceptions for students who could, due to individual circumstances, not participate to the positioning test.

1.4 Research questions

The two research questions handled in this paper are: How does the mandatory participating to a test prior to entering an Engineering Bachelor program impact: (1) *the diversity* regarding gender, socio-economic status, pioneering status, and disability among new engineering bachelor students?; and (2) *the academic achievement of the diversity target groups*?

2 METHODOLOGY

This paper takes a quantitative approach to study the impact related to gender and diversity of the governmental decision, taken in 2018, to make participation to the positioning test mandatory for subscription in the Bachelor of Engineering Science in Flanders, Belgium. The study is performed for the Bachelor of Engineering Science of KU Leuven. Longitudinal data of the last 10 years was obtained in collaboration with the University's central service on diversity, which provides detailed and fully anonymized yearly reports regarding gender and diversity of incoming students and how they progress in the program. This study focuses on generation students, these are students who subscribe to a higher education for the first time, and whom are therefore also the target audience of the positioning test. Typically, they constitute 96% of the students who enter the program. This paper focuses on: (1) **gender**, with a focus on female students; (2) **pioneering students,** students of whom neither parents has a diploma in higher education, (3) students with **socio-economic challenges** (scholarship, migrant background, and/or pioneering status)[2], and (4) students with a learning **disability**[2]. The impact on the *diversity of the incoming population* is studied by monitoring the percentage of students that belong to each of the above target groups and by comparing it to the evolution of these target groups

[2] As the reporting of scholarship status and disabilities is only closed in June, no data for 2019 can be reported so far.

at the university level (same campus). The impact on the *academic achievement of the target groups* is studied by monitoring the percentage of students of the target groups that obtain a high study efficiency (obtained at least 80% of the credits after one year) and a low study efficiency (obtained less than 30% of the credits after one year), and by comparing it to the study efficiency of non-target group students.

3 RESULTS AND DISCUSSION

Before digging deeper into gender and diversity, the **impact on the number of students** is reported. The year of the introduction of the mandatory participation the number of students suddenly decreased (-8.2%). One year later however, the largest increase in 10 years (+21.4%) was observed, resulting in the largest number of students (520) in the program since the start of the central reporting (2005). We can conclude that the introduction of the mandatory participation to the positioning test had a short-term negative effect, which was promptly recovered from, resulting in the end in attracting more students than before.

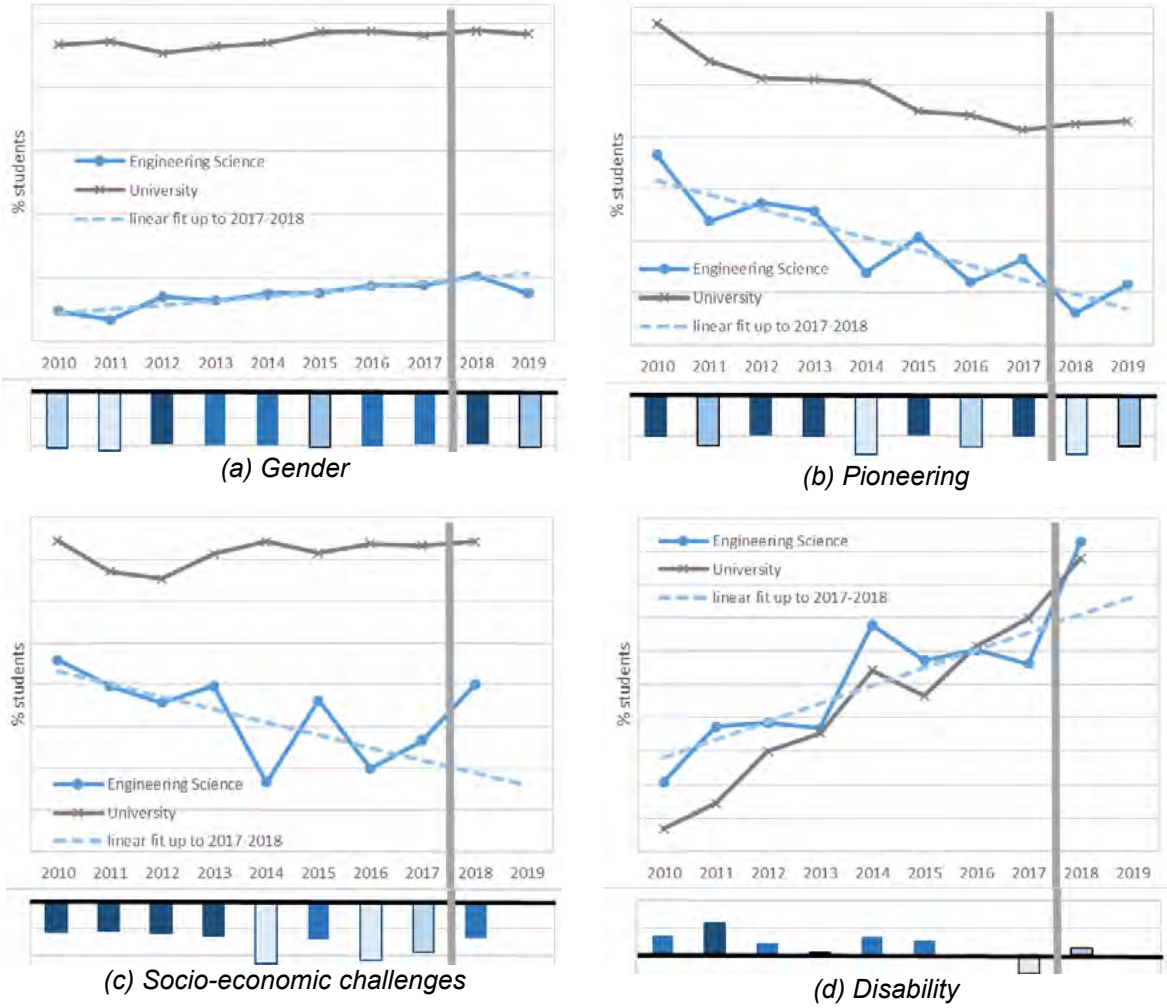

Fig. 1: Evolution over time of the percentage of particular target groups (a,b,c,d). The vertical grey bar represents the introduction of mandatory participation to the positioning test. Each of the top graphs shows the evolution of the percentage of students of a particular target group within the Engineering Science bachelor (blue line) compared to the percentage at university level at the same campus (grey line). The dashed line shows a linear fit to the before the introduction of the mandatory participation, allowing to check how the following years (2018, 2019) deviate from the expected trend-line. Each of

the bottom graphs shows the evolution of the difference between the percentage of students of that target group in the Bachelor of Engineering Science program and the university.

Fig. 1 visualizes the impact on the **representation of target groups**. The first year after the introduction of the mandatory participation to the positioning test the percentage of **female** students continued its slow but rather steady increase, resulting in the largest ever reported percentage of female students in 2018. Taking into account the overall decrease in student population in 2018 (Section 3.1) no change in the absolute number of female students was however observed with respect to 2017. We therefore conclude that female students were initially less influenced by this new hurdle to come to university than male students. In 2019 however, the percentage of female students again decreased, going back to the level of around 2015. In absolute numbers however, 2019 counted the largest number of female students since the beginning of the reporting. For the **pioneering** students, no deviation from the trend over the different years could be observed. For students with **socio-economic challenges,** until 2016 a steady decrease in the percentage of students with socio-economic challenges was observed, causing an increasing gap with the university level. One year after the introduction of the mandatory positioning test the percentage of students with socio-economic challenges suddenly increased up to the level of 2011. Despite the lower number of students in 2018, the absolute number of students with socio-economic challenges also increased after the introduction of the mandatory participation to the positioning test. Both at the university and at Engineering Science the percentage of students with **disabilities** is growing steadily over time. The introduction of the mandatory participation did not stop this trend. Even more, both the percentage of students with disabilities as the absolute number of students with disabilities has never been higher.

To study the impact of the mandatory participation of the positioning test on the **academic achievement** of the target groups we studied two indicators: the percentage of students with high study efficiency (≥80%, Fig. 2) and low study efficiency (<30%, Fig. 3). Study efficiency is the ratio of the successfully obtained credits points and the total number of booked credits points (typically 60). **Female** students are in general, despite being underrepresented in the program overall, overrepresented in the high-achieving group (Fig. 2a) and underrepresented in the low-achieving group (Fig. 3a): on average they perform better in Engineering Science than male students. The introduction of the mandatory participation to the positioning test did not break this trend. In contrast to female students, **pioneering** students are underrepresented in the high-achieving group (Fig. 2b) and overrepresented in the low-achieving group (Fig. 3b). For these students, the positioning test had a positive impact: the gap between the academic achievement, hereafter referred to as the performance gap, of pioneering and non-pioneering students decreased. The decrease in the percentage of pioneering students with low study efficiencies especially contrasts with the increase of the percentage of non-pioneering students with low study efficiencies. The positioning test decreased, but not yet eliminated the performance gap. For students with **socio-economic**

challenges, who as pioneering students are underrepresented in the underrepresented in the high-achieving group (Fig. 2c) and overrepresented in the low-achieving group (Fig. 3c), the impact is less clear. The gap in the high-achieving group increased, while the gap in the low-achieving group decreased. Further monitoring is required to understand the impact on this student group. For students with **disabilities** the impact was so far remarkable. Historically, students with disabilities were underrepresented in the high-achieving group (Fig. 2c) and overrepresented in the low-achieving group (Fig. 3c). In 2018 however, since the first time ever, the percentage of high-achieving students was higher in the group of students with disabilities than in the group of students without disabilities. The closing of the performance gap was already achieved in 2017 for the low-achieving students, in 2018 this positive trend continued: for the second year in a row the percentage of low-achieving students within the students with disabilities was lower than the percentage of low-achieving students within the students without disabilities.

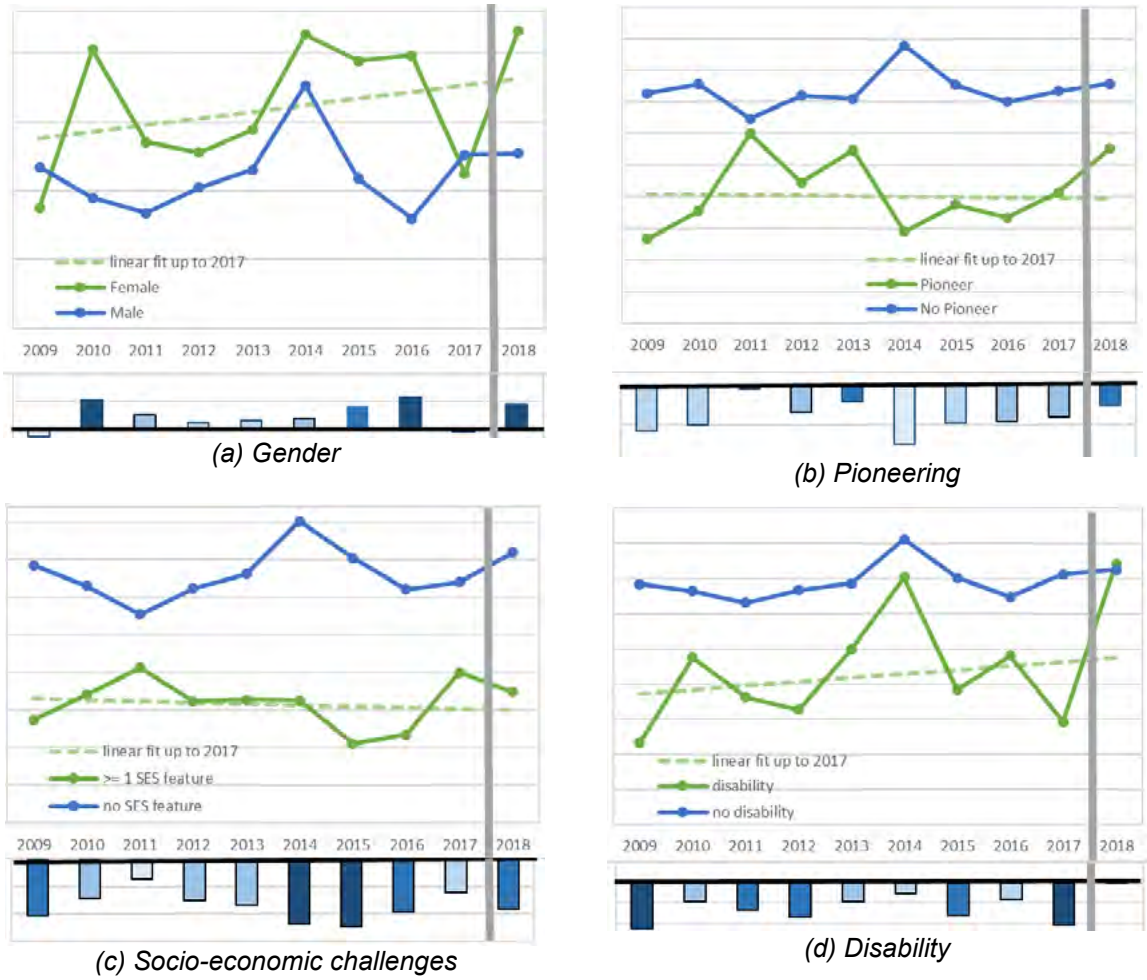

Fig. 2: Evolution over time of the percentage of students of a particular target group (a,b,c,d) with high study efficiency (i.e. obtained ≥ 80% of the credits) after one year. The vertical grey bar represents the introduction of mandatory participation to the positioning test prior to academic year 2018. Each of the top graphs shows the evolution within the bachelor of Engineering Science of a particular target group (green line) compared to the remaining part of the study population (blue line). The dashed green line shows a linear fit to the target group for the years before the introduction of the mandatory participation, allowing to check how the following years (2018, 2019) deviate from the expected trend-line. Each of the bottom graphs shows the evolution of performance gap, the difference between the

percentages of students with high efficiency of the target group compared to the percentage of students with high study efficiency of students who are not in the target group.

4 SUMMARY

This paper used a quantitative and descriptive approach to study the impact on diversity of the governmental decision to make participation to the positioning test mandatory for aspiring engineering students. At the global population level an obligatory but non-binding entrance test was found, despite an effect in the first year, not to hinder entrance to an Engineering Science bachelor program and even result in a growing student population. As

*Fig. 3: Evolution over time of the percentage of students of a particular target group (a,b,c,d) that obtained **a low study efficiency** (i.e. obtained <30% of the credits) after one year. For more information regarding the graphical representation see the caption of Fig. 2.*

the representation of students with socio-economic challenges and disabilities increased, the mandatory participation to the positioning test was no hurdle to them. While the representation of pioneering students seemed to be unchanged, two years after the introduction of the positioning test the percentage of female students, while still increased in absolute numbers, decreased. Therefore, in the future particular attention should be spend to the representation of female and pioneering student. Regarding academic achievement the mandatory participation to the positioning test

did not influence the better performance of female compared to male students, and reduced the gap for pioneering and learning-disabled students. Notable, for the first time ever high-achieving were more frequent ánd low-achieving students were less frequent among students with disabilities compared students without disabilities. For socio-economically challenged students the picture is mixed: while the gap in low-achievement was reduced, the gap in high-achievement increased. Therefore, in the future particular attention should be spend to the achievement of students with socio-economic challenges.

The paper has some limitations. As the mandatory participation to the positioning test was only introduced two years ago, only data of two years and even one year for student performance, was available. The upcoming academic years have to show if the observed trends will persist. So far, only a descriptive analysis of the data was performed without statistical tests. As data of more academic year is available such a statistical analysis will become a valuable next step. Furthermore, a qualitative study using interviews with positioning test participants and students would help to interpret the trends and shed light on individual student trajectories.

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IMPROVING INTEGRATION IN UNIVERSITIES FROM A STEM STUDENTS' PERSPECTIVE

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Conference Key Areas: *Diversity and inclusiveness. Internationalisation, exchange options, joint programs.*
Keywords: *STEM education, Students' opinion, Inclusiveness, Integration, Diversity*

ABSTRACT

In recent years diversity, equity, and inclusion have been broadly discussed in terms of the impact they can have on society. Being in a diverse environment during one's studying period has been shown to enhance several skills, including teamwork and communication. Nevertheless, the current Higher Education system does not always provide a discrimination-free setting which enables such cognitive growth. Hence, it is crucial to promote the integration of diverse groups in STEM education and foster such integration with concrete actions.

This paper aims to display European STEM students' perspectives on integration methods within universities, with a focus on cultural and gender diversity. The students' points of view were collected through a survey on diversity and multiple sessions designed with different formats. These sessions were held in BEST Symposia on Education (BSEs), which are live events organized by the Board of European Students of Technology (BEST).

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This research aims at lowering socio-cultural barriers that exist in universities and influences students' lives by proposing a set of applicable actions. Initially, this study discusses the identified barriers and how they affect the learning experience. Then, it suggests actions that can be taken to overcome such barriers, tailoring them for the different stakeholders involved. This paper draws its conclusions based on the opinions of STEM students and it can provide insights and actions that professors, universities' management, students, and associations involved in Higher Education can adopt to create an inclusive and discrimination-free environment.

1 INTRODUCTION

In recent decades, globalisation has been profoundly changing the structure of our communities and our lives. Nowadays, our society has been evolving into a globally interconnected world, increasing people's mobility and the possibility to interact with individuals from different backgrounds. In this changing scenario, today's graduates are expected to be able to work in highly diverse teams across different cultures [1, 2]. Among the new skills that need to be developed, we find creativity, collaboration, and interpersonal dynamics. Studies have shown that students who experience a diverse environment develop adaptability, cross-cultural communication skills, and conflict-resolution skills that ultimately lead to improving productivity and performance [3-5]. Hence, Higher Education should adapt itself effectively and efficiently in order to provide society with a suitable workforce.

Nevertheless, in Science, Technology, Engineering, and Mathematics (STEM) a discrimination-free and inclusive environment has not been reached yet. When dealing with diversity, and the lack of it, the main focus is raised on attracting talents who belong to underrepresented groups, be it for cultural differences, disabilities, gender, or sexual orientation [6]. However, confining the problem to the recruitment area is not solving the issue; the necessary step forward to be made is inclusion. A university that cares about inclusion aims to ensure that the needs of diverse groups are properly addressed. By doing that, universities create an environment that allows students from various backgrounds to feel welcome and comfortable, such that they want to stay enrolled [7].

This paper explores the opinions of STEM students regarding diversity, cultural barriers, and integration techniques through the analysis of reports written by the Board of European Students of Technology (BEST). With a network of 93 universities in 34 countries, BEST is a non-political, non-governmental, and non-profit voluntary students association committed to supporting students' self-development in an international environment. To achieve this goal, BEST offers a set of different events that are intended to bring universities, companies, and students closer.

2 METHODOLOGY AND MATERIALS

The Educational Involvement Department of BEST is a dedicated body of the organisation that aims at connecting STEM students with contemporary educational needs on engineering education. Through the work of this department, BEST strives to gather, analyse, and disseminate the students' ideas on what can be improved in their universities, study programmes, and curricula and share it with relevant stakeholders. The department work's is structured around Educational Involvement Programmes, which are biennial focused research on a broad topic. In the biennium September 2018 - September 2020 BEST committed to gather information, analyse and study the topic of Diversity in STEM higher education by collecting students' opinions through a survey and live events. The goal of such a research programme was to collect qualitative input from European STEM students from diverse backgrounds and disseminate their opinion to relevant stakeholders.

This paper bases its conclusion from three live events which happened within the context of the Educational Involvement Programme on Diversity: the BEST Symposia on Education (BSEs) in Aveiro (2019, "Light, camera, educACTION!"), Athens (2019, "Plato's Symposium Vol II: Diversity"), and Skopje (2019, "STEMbox: Open your eyes and see the diversity"). BSEs are live events that allow students to actively contribute to the discussion on Higher Education thanks to carefully designed sessions. These sessions are created beforehand by the Educational Involvement Department of BEST through the work of the facilitators/content team of the event. Each one of these events has three to four facilitators whose role is to direct the discussion in such a way as to ensure inclusivity in the event. During these sessions, various facilitation methods are applied such as Brainstorming, World Cafe, Sharing Session, SWOT analysis. All information collected from these sessions is processed to create a final report of the event on which this paper is based. In order to have representative outcomes, in each of these events more than 20 STEM students from different countries are selected per event, based on gender, academic qualifications and origin to ensure diversity. In addition, this study takes into consideration the results obtained through a survey on Diversity in STEM Education conducted by BEST between October 2018 and April 2019. The survey was disseminated among the universities where a BEST local group is located and collected more than 400 anonymous answers. The topic of diversity was first addressed at diversity in general and then deepened into three categories: cultural diversity, gender diversity and disabilities. Within the scope of this survey, the general introduction and the first two dedicated sections are taken into consideration.

3 ACTIONS TO IMPROVE INTEGRATION IN UNIVERSITIES

This section discusses barriers that prevent universities from offering an inclusive learning experience with respect to cultural and gender diversity. For both types of diversity, first the identified barriers are introduced; then, tailored actions are presented for each of the three key stakeholders: universities, students, and NGOs.

3.1 Cultural Diversity

The existence of various ethnic or cultural groups in a society is defined as cultural diversity. Our lives are constantly impacted by cultural diversity, be it in the professional, academic or private domain. Its consequences can be different for us or our society depending on where it occurs [8]. The existence of multiculturality is of high importance in an educational environment in today's world [9]. This statement was further emphasized by the survey conducted by BEST where 42.39% of the interviewed students strongly agreed and 37.31% partially agreed that multiculturality is an important factor in the quality of higher education.

3.1.1 Universities

During BSE Athens, participants concluded that ethnic segregation, unequal evaluation, language barrier, and lack of curiosity are the main cultural problems that are faced by students in universities. The participants suggested the following solutions for each of the above-mentioned issues [8]:

- Segregation: forming culturally diverse teams for projects was discussed as a solution to the problem of segregation as it would enable international students to interact and collaborate with local students in an academic environment and promote learning. Another solution can be a "buddy" or mentoring programme, which is already used in some European universities. Having a local student assigned to an international student can help them obtain practical help but also learn more about the country's culture and habits. A successful mentoring system is also beneficial in helping international students integrate smoothly into the academic system by getting guidance on the areas to pay attention to. In addition, it can be used to obtain personal help in case of need and should have both local and international students involved as mentors to make the international students feel more comfortable to connect and share.
- Unequal evaluation: participants observed that equal evaluation for local and international students is not yet always achieved. Universities should work on providing a unique evaluation metric. On this topic, it was suggested that a more regulated and strict system for all universities would make things more transparent in terms of evaluation.
- Language barrier: it can be diminished by encouraging professors to take English courses for better communication, and enhancing the quality of the English courses offered while also focusing on non-technical vocabulary.
- Lack of curiosity: it can be increased by effective promotion of international opportunities and benefits like scholarships and internship programs.

Furthermore, participants highlighted that a successful collaboration between universities and NGOs is essential in ensuring a balance in cultural diversity. NGOs and student organizations organize extra-curricular activities that can develop

students outside the classroom. However, these are not always supported by universities. Among various issues in the cooperation, it was reported that universities need a physical space or an office where information regarding clubs and organizations is available since the university websites do not contain this information [8].

Promoting international exchanges is also seen as a way to increase the interaction of students from different cultures and help them tolerate different cultures [8]. However, there are different problems associated with mobility programs, the solutions to which were discussed in the BSE in Skopje [10]. According to students, one of the biggest problems is that Erasmus exchange programs can be expensive; a scholarship or support from either the government or university can help mitigate this problem and make exchange opportunities accessible for everyone. In addition the majority of the students that filled the survey conducted by BEST agree that cultural diversity, which can be enhanced by such mobility programmes, is vital to the improvement of quality in STEM higher education, as shown in Fig.1.

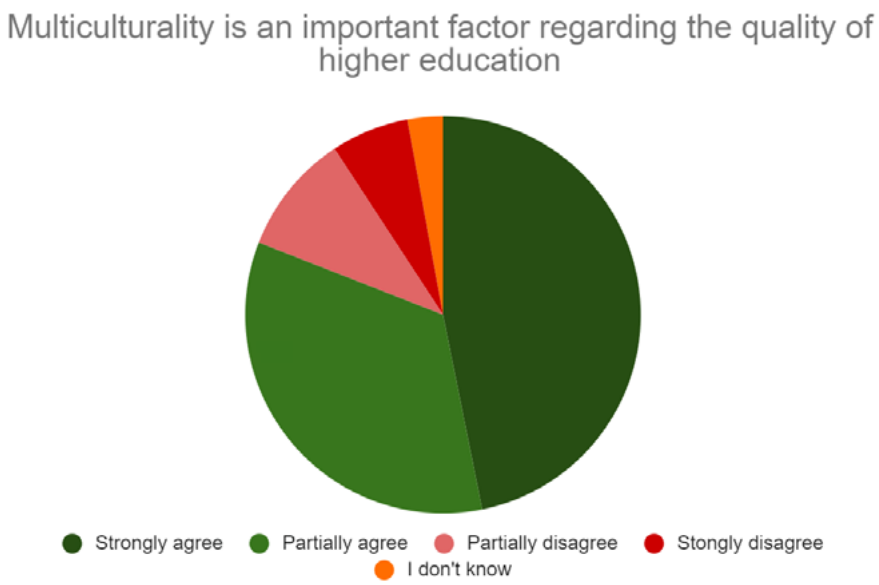

Fig 1: Students' responses on the statement: "Multiculturality is an important factor regarding the quality of higher education.". These data come from the survey on diversity conducted by BEST during 2018 - 2019.

3.1.2 Students

Working with students from different cultures can be challenging and disagreement on working methods was seen as a common problem. A solution to this problem was reaching a consensus on working methods by the students at the beginning of projects or courses to avoid problems and confusion during it. Furthermore, the implementation of a mentorship system as the one proposed in 3.1.1, can be jointly executed through an initiative by students in a university. Most universities have

student representatives in the form of a council, a link to the senate, etc. However, these representatives mostly help with matters regarding education and are not that involved when it comes to cultural diversity. It was discussed that the transparency regarding the work of these representatives should be improved by sending periodic reports or emails to the students. Additionally, these student representatives and their organizations should actively participate in matters concerning cultural diversity, possibly with a representative for international students [8].

3.1.3 NGOs

One of the outcomes from the BSE in Skopje was that diversity and integration should be high priorities for NGOs and they should always be welcome to accept all kinds of students by organizing integration activities [10]. Evidently, there is a significant need for cultural education in order to bridge the gap in mentality. Events like cultural evenings done by student associations were identified to help in contributing towards this gap in mentality by making students aware of different cultures by letting students talk about their country, traditions, food, etc. NGOs and student organizations along with universities should also organize competitions where international and local students can collaborate and interact together, also on a personal level [8].

3.2 Gender Diversity

Gender equality refers to the equal enjoyment of their rights, responsibilities, and opportunities and it implies that the interests, needs, and priorities of each gender are respected. Despite the effort in reducing the gap carried out in recent years, studies show how women in STEM education and profession are still underrepresented [11]. This perception is aligned with students' perspective about gender representation in STEM studies: only at one out of the seventeen universities represented in the BSE Aveiro, the gender percentage was perceived as 50-50 [12]. Considering the outcomes of the survey on diversity conducted by BEST, we have comparable results: as seen in Fig. 2 and Fig. 3, the respondents perceive that in their faculty the majority of people are male, both when taking into consideration the whole department and the teaching body only. In further discussions on this topic, participants stressed how having a bigger variety of perspectives, among which different genders, leads to better problem-solving skills.

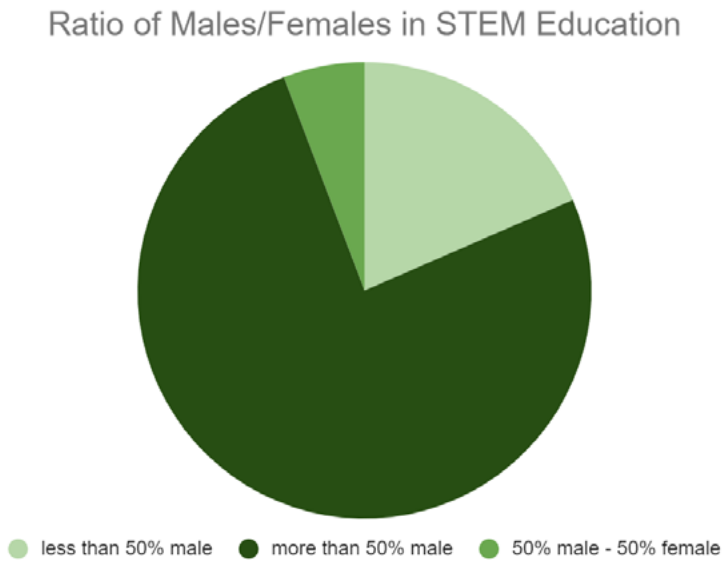

Figure 2: Students' responses when asked about the ratio of males to females in their faculty (students, professors, administrative personnel and management). These data come from the survey on diversity conducted by BEST during 2018 - 2019.

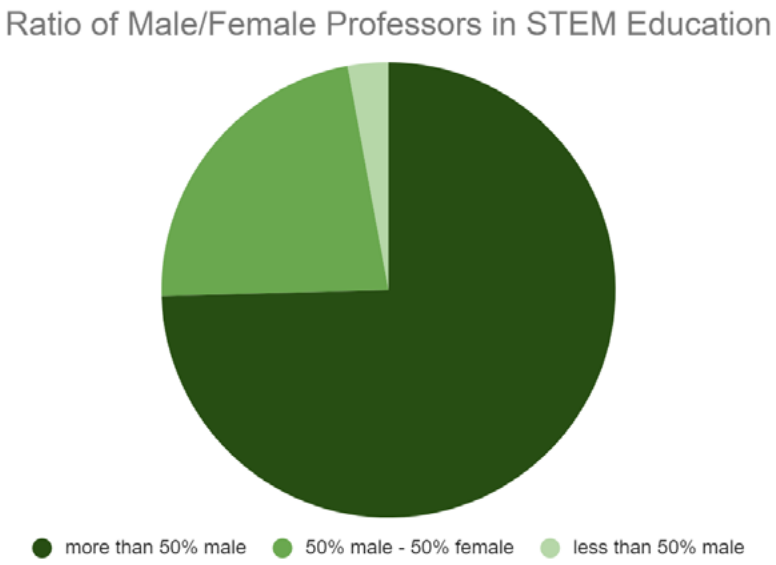

Figure 3: Students' responses when asked on the ratio of male to female professors in their faculty. These data come from the survey on diversity conducted by BEST during 2018 - 2019.

3.2.1 Universities

Given the key role universities have in shaping our society, it is important that the European Higher Education system creates an environment in which gender diversity and inclusivity can properly be achieved. In addition to the importance of reaching such a healthy environment for an optimal learning experience, students consider universities that minimize gender inequality as more meritocratic.

In various sessions of the aforementioned BSE, many problems linkable to gender diversity were brought up. After brainstorming and clustering them, participants agreed on this set of barriers as being the most important one to be tackled: lack of opportunities, lack of action, sexism and harassment, discrimination, and stereotypes. In order to tackle such barriers, participants created an action plan to support gender equality in Higher Education and foster a diverse environment. The most relevant actions included to fight the different problems are:

- Lack of equal opportunities: build proper universities policies to evaluate impartial behaviour from the teaching staff, ensure that the sponsored job-advertisements are gender-neutral.
- Lack of action: create a feedback system to identify problems earlier, establish procedures to denounce faultily behaviours, increase training opportunities on diversity and gender equality.
- Sexism and harassment: take concrete actions against offenders, organize training sessions on the matter, raise awareness through public channels and events.
- Discrimination and stereotypes: anonymous feedback and evaluation systems, establish policies to control discriminatory behaviours.

In addition, participants pointed out the disparity in gender employment at universities. When asked about women's participation in STEM studies, students observed that, while in teaching and administration the percentage of females is about the same as males, management is still a predominantly male role. This matches industry standards [11] and contributes to the problem of the lack of female role models in STEM professions. To counteract this barrier, universities should advertise and promote success stories of women in STEM fields, organize events with such well-known figures and actively use social media to share women's voice equally as their male peers.

3.2.2 Students

Among various stakeholders, students themselves can have an active role in fighting gender inequalities. Complementary to the actions presented in the previous section, during the BSE Aveiro [12], participants proposed a set of actions that students themselves should carry out to promote gender equality. These measures aim at lowering the identified barriers: lack of action, discrimination, stereotypes, and biases.

The actions are focused on students' role within the Higher Education system and are deemed practicable by BSE participants.

- Lack of action: reports incidents of any gender mistreatment or behaviour; actively use and request university support when a problem is identified.
- Discrimination: increase student awareness on gender equality issues via discussion and support groups;

- Stereotypes: establish a culture of equality by example, promote mix-gender activities.
- Biases: raise awareness of the potential impact of unconscious biases, speak-up when biased or discriminatory behaviour is witnessed.

3.2.3 NGOs

The positive impact that NGOs can have in Gender Diversity is tackled in BSE Athens [8] and BSE Aveiro [12]. Students mentioned NGOs as positive actors in promoting gender equality as often such organizations organize competitions and events which encourage gender diversity. Participants in BSE Aveiro believe that students organizations can help to reduce gender inequality by raising awareness on the topic during their activities, provide a discrimination-free support group, incentive mixed-gender group work, and address issues with university management.

Although they do provide students with opportunities for extra-curricular activities that formal education does not offer, some universities tend not to support organizations mainly due to financial and bureaucratic reasons. Often NGOs perceive a low support from local institution when it comes to office and logistics need, bureaucracy in dealing with university regulation and organization of activities, and opportunities of promotion within the campuses.

4 CONCLUSION

Diversity and inclusion have been broadly discussed in a European Higher Education setting; on this matter, a relevant voice to be heard is students'. As highlighted in this paper, STEM students can provide numerous suggestions to enhance diversities in their studies and thus to tackle the problem of integration of diverse groups. BSEs provide students with a platform to share their opinions, discuss problems and propose solutions to the raised issues. Therefore, the suggestions gain more value due to the experiential perspective the students give them. STEM students have made it evident that they would have a more meaningful learning experience if they were given the chance to work in a more diverse and inclusive group. Thus, with this paper, we see an opportunity for young people to set a new trend of inclusiveness and cooperation under the guidance of experienced people and experts in their field of studies.

The series of actions we showed to tackle cultural and gender diversity were selected as students considered them to have a high impact on the quality of their education and the fairness of the university system. According to students' perspective, the solutions offered above are practical and achievable, and therefore it is now on the various stakeholders to take initiative and work together to promote integration and break the barriers of diversity. Mostly, those actions require the stakeholders to get a better understanding of the benefits that gender and cultural diversity can bring in an educational environment, through various methods. Future

work can vary from validation studies on the effectiveness of the proposed solutions to further research on methods to improve integration and sense of belonging.

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INTEGRATING ETHICS ACROSS THE ENGINEERING CURRICULUM THROUGH SUSTAINABILITY AND LEGISLATIVE TOPICS

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ABSTRACT

The paper explores the inclusion of sustainability and legislation related coverage in Engineering programmes in Ireland in the context of increasing calls for integrating ethics across the curriculum. It is part of a broader study examining engineering ethics education conducted in cooperation with the national accrediting body, Engineers Ireland. The study includes 23 Engineering programmes from 6 institutions in Ireland that underwent accreditation between 2017-2019. Mixed research methods have been employed, such as documentary analysis of module descriptors and of materials submitted for accreditation, as well as interviews with evaluators serving on accreditation panels and lecturers within the participant programmes. This led to the identification of two main themes employed to convey ethical content that are deemed to be suitable candidates for the integration of ethics across the curriculum, with coverage present in a wide variety of modules, such as technical modules, design modules, professional formation modules, final year projects, work placement, business and legal studies modules. We examine how each of these two main themes purporting to sustainability and legislation have been employed for the integration of ethics across the curriculum, by looking at the teaching and assessment methods employed. Our contribution thus aims to provide insights and examples that can guide programme chairs and lecturers in the implementation of ethics in varied module types across the curriculum.

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1 INTRODUCTION

Recent years witnessed a greater call for integrating ethics across the engineering curriculum, in modules with both a technical and non-technical orientation ([1]; [2]; [3]; [4]). There are several advantages mentioned in connection to teaching and assessing ethics in several modules throughout an engineering programme, such as providing a holistic and interdisciplinary approach that "mirrors the ways in which ethical issues arise in day-to-day engineering practice" ([1], p.545), thus allowing students "to see ethics in action" ([4], p. e114). The integration of ethics across the curriculum also helps students become aware of the intrinsic connection between ethical concerns and technical content, by rectifying the preconception that ethics is just an "add-on material" ([2], p.346). As such, this approach is considered to be more effective in improving engineering students' moral reasoning and sensitivity to ethical issues than solely having dedicated modules on ethics ([3], p.223). Nevertheless, there are also significant challenges reported about the method of implementing ethics across the engineering curriculum. The most significant challenges relate to the background of engineering lecturers and their lack of familiarity with societal and ethical related topics [2], but also students' reticent attitude towards ethics [5].

Our paper examines the integration of ethics across the curriculum in engineering programmes in Ireland through the prism of sustainability and legislation related coverage. These topic areas fall under one of the seven criteria listed by Engineers Ireland [6] that Engineering programmes have to demonstrate for accreditation. Programme outcome E dedicated to ethics requires graduates to show "knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline", as well as "knowledge … of engineering practice, and the impact of engineering solutions in a societal and environmental context" and "commitment to the framework of relevant legal requirements governing engineering activities, including environmental." Furthermore, it has been pointed out that a focus on sustainability and policy may provide a means for broadening engineering ethics education beyond a micro ethical approach ([7]; [8]; [9]; [10]; [11]).

We argue that sustainability and legislative related coverage can be good candidates for integrating ethics across the curriculum. The paper provides insights and examples that can serve as guidance to lecturers and programmes in light of an expressed need for guidance on how to implement ethics across the engineering curriculum ([10]; [12]).

2 METHODOLOGY

In order to determine the implementation of ethics in Engineering programmes in Ireland, three research methods have been employed: (a) document analysis of the documentation which was either prepared by the programmes for accreditation or is available online on the website of all 23 participant programmes; (b) participant observation at the accreditation events of 11 programmes offered by 3 insititutions and (c) interviews with lecturers from the participant programmes teaching a professional

formation module and evaluators who served in the accreditation panel during the events observed. These methods are seen as complementing each other in order to develop a comprehensive insight into the implementation of ethics education in the participant programmes.

The scope of the study was limited to Engineering programmes that underwent accreditation between 2017-2019. Twenty three programmes offered by 6 institutions are included. Our analysis focuses on modules that the programmes themselves have deemed to have the highest contribution to meeting programme outcome E for accreditation. To identify these modules, we relied on a mandatory rubric in the documentation submitted by the programmes for accreditation, in which the programmes self-assess how they meet each of the seven programme outcomes. Thus, the modules that were assessed by the participant programmes with the highest contribution to outcome E were singled out for a documentary analysis of the topics and learning outcomes employed in connection to ethics instruction.

The documentary analysis relies on two main data sources: a rubric present in the documentation submitted by the participant programmes for accreditation, by which the programmes describe how they meet programme outcome E, and the module descriptors provided either as an annex to the documentation submitted for accreditation (6 programmes), part of the evidence presented during the accreditation events observed (11 programmes) or posted online on the programmes' website (6 programmes). At the end of this stage, there was a total of 83 unique modules with a strong contribution to meeting programme outcome E. The next research stage was dedicated to analysing the content input from the previous stage, following two iteration steps. First, a codebook was generated with 28 initial codes covering curricular content purporting to ethics informed by the standard description of topics falling under outcome E [6] and the literature about the content of engineering ethics education. Then a second iteration followed, which grouped the initial thematic codes under broader categories.

Having established the major themes employed to teach ethics in the participant programmes, we sought to get a more in-depth exploration of the topics and methods used to teach ethics. This was achieved through a series of interviews. Sixteen lecturers of professional formation modules were questioned about the topics and methods employed in teaching ethics. Six evaluators who served on the panels of Engineers Ireland during the accreditation events of 3 institutions observed by the researcher, were also interviewed. The evaluators were questioned about their views on engineering ethics education and its implementation in the evaluated programmes.

3 IMPLEMENTING ENGINEERING ETHICS EDUCATION ACROSS THE CURRICULUM: THE EVALUATORS' PERSPECTIVE

All six evaluators interviewed for the study showed a preference for seeing ethics integrated across the curriculum rather than in dedicated modules. This approach is considered to foster the development of holistic engineering graduates that do not

divorce ethics from the technical solutions they pursue. As one evaluator claims, “that is the way it has to go if we want to produce engineers that consider ethics as part of their direct reasoning.” Another evaluator argues that ethics “has to be across, we do not just want to see it in the professional development modules, you would like to see some mention of it elsewhere in the other modules as well. […] You cannot just be ethical in one module, there should be an element of it everywhere.” This opinion is shared by a third evaluator who considers that “ethics possibly should be brought into more modules as opposed to just being covered in a module”. The reasoning behind this preference is that having ethics addressed in a dedicated module could contribute to the perception of the topic as an add-on, “just to get it in the course", and thus minimizing its importance in the engineering curriculum.

Based on the interviews conducted, there is a sense that technical and ethical issues need to be “combined and fused in real life situations.” Nevertheless, evaluators consider that engineering programmes are not yet at the stage of implementing ethics across the curriculum. “It is not quite there yet. I do not see any programmes where it is permeating throughout”, states one evaluator, while another evaluator agrees that “most modules do not cover ethics. In any module that has a high technical content, probably ethics is not covered there.”

A challenging aspect according to one of the evaluators is that “for some modules it is going to be hard to bring it into light”. This point is expanded by another of the evaluators questioned. Accordingly, “it is very difficult because of the way the existing crop of academics were taught engineering was in a very different way to the way we are teaching engineering now”, which leads to a “slow process of getting people to think more holistically in their approach to engineering education”. There is an agreement among the evaluators for the need for more guidance on how to implement ethics more effectively, especially in the case of technical modules.

4 SUSTAINABILITY ACROSS THE CURRICULUM IN PRACTICE

When analyzing how ethics is being integrated in the curriculum of the participant engineering programmes from 6 HEIs in Ireland, we found that sustainability is the most popular theme employed in connection to meeting programme outcome E for accreditation. Table 1 shows that 49 (59%) modules deemed to have a high contribution to outcome E incorporate sustainability related topics. The topics mentioned in connection to the teaching and assessment of the theme of sustainability are the principles of sustainable development, environmental impact and protection, climate change, carbon management, energy efficiency, renewable energy, life cycle analysis, waste management, sustainable economic growth and eliminating poverty traps. We also note a higher emphasis on the environmental dimension of sustainability than on its social and economic dimension.

The theme of sustainability is covered in a wide variety of module types, such as technical modules, design modules, professional formation modules, capstone projects, work placement programmes, business studies modules as well as legal

studies modules[2]. More so, as seen in Table 1, sustainability related coverage is present in more than half of the modules that have a strong contribution to outcome E from each module type. This suggests that sustainability might be a good candidate for integrating ethics across the curriculum

Table 1: Distribution of sustainability related coverage across module types (n=83 modules)

Technical modules (n=36)	Design modules (n=15)	Professional modules (n=12)	Capstone Projects (n=8)	Work Placement (n=2)	Business studies modules (n=6)	Legal studies modules (n=3)	TOTAL %
19	10	8	5	1	4	2	**59%**

From the perspective of lecturers, sustainability has the advantage of being a theme that suits the technical expertise of engineering faculty members. As one lecturer states, sustainability coverage has “the potential” to be integrated in technical modules. According to her, ethical questions about energy efficiency and waste production “did resonate because people could see how they might be involved in something that could be problematic”. Sustainability is also found to be appealing to students, who were found to show “a real interest.” Reflecting on the classroom experience, one lecturer noticed a real focus on the Sustainable Development Goals, with students commenting that “this was something they really enjoyed”.

These observations seem to address two common challenges highlighted by current research on engineering ethics instruction. One such challenge is the engineering faculty’ lack of familiarity with the topic, which hinders the linkage of ethical concerns with technical subject matters ([13]; [14]; [15]; [16];]17]). A second challenge is the students’ negative reception and engagement with nontechnical content ([15]; [16]; [18]).

Sustainability is present in the curriculum of the participant programmes both in taught components and assessments. In what follows, we describe some of the evidence of sustainability coverage in both these components. Table 2 shows that the participating programmes incorporate sustainability topics through various taught components, such as lectures, case studies, community service, online polling systems and documentaries.

Some examples of topics introduced in lectures are the principles of sustainable development, environmental policies and standards, environmental and ecological theories representative of the Western, Buddhist and Native American traditions and the role of engineering in addressing wealth inequality. The topics included through lectures show a concern with both the environmental and socio economic dimension of sustainability.

[2] An exception, considered insignificant, is for the only module categorized as a personal development module in light of its focus on learning outcomes related to healthy lifestyle, time management a.s.o. This module does not offer coverage related to sustainability.

The case studies used by the lecturers interviewed aim to foster students' reflection on the implications of developing technologies that fail to meet environmental standards. For example, a case study about wastewater treatment using realtime data explores the "(un)certainty of knowing" that the discharge from the respective technology is "actually polluting the environment or was it just that we took one sample and that sample is inaccurate?" Students are exposed to the various type of ethical concerns that arise, such as "the rigor and integrity of their data collection and management, the cost benefit of different solutions, and the impact of one solution over another."

Community engagement has been mentioned in connection to designing "socially-conscious building retrofits that are student initiated and with clear relevance to societal contribution and community awareness". While an example of documentary shown in class addresses "what is progress from a critical perspective, looking at various aspects of sustainability and how they are interlinked." Online polling systems have been used by one lecturer to ask students to input the moral decisions they make in their daily lives for tackling climate change.

Table 2 Teaching methods incorporating sustainability issues

Type	Example of content
Lectures	Principles of sustainable development The relationship between a country's GDP and associated energy use Wealth inequality Local and/or international environmental policies and legislation Environmental ethics, inclusive of different traditions of thought
Case studies	Ethical dilemmas about sustainability aspects
Community service	Developing environmentally-friendly and/or socially-conscious solutions based on needs identified through direct interaction with a non-profit entity or a community group
Online polling systems	Exploring students views on different aspects of sustainability
Films and documentaries	Surviving Progress, The True Cost, A Plastic Ocean, A Cadillac Dessert

We see that the integration of several various teaching approaches leads to a more holistic approach to the topic of sustainability, which incorporates its three pillars of environmental protection, economic viability and social equity. This seems to suggest that a hybrid approach to the incorporation of sustainability in the engineering curriculum is needed in order to offer students a more rounded understanding of the topic.

In order for the integration of ethics across the curriculum to be successful, it was argued that the inclusion of ethics in taught components is insufficient by itself if it is not accompanied by an assessment of the ethical components of technical modules ([19], p.1132). [20] agrees that the inclusion of ethical and social reflection in "even 10% of homework and exam questions", could reverse engineers' "slide into disengagement." In what follows, we present several examples of the integration of sustainability aspects in the assessment methods employed by the participant programmes. As seen in Table 3, sustainability was found to be included in exam question, research projects, design projects and capstone projects.

Table 3 Assessment methods incorporating sustainability issues

Type	Example
Exam questions	discussing the ethics of landfilling
Research projects (reports, posters and presentations)	about the sustainable development goals about the state of energy legislation in Ireland and the EU identifying stakeholder positions in national debates on adoption of wind energy or current ban on nuclear power
Lifecycle assessment analysis	Whether EV are an environmentally friendly solution
Design projects	Projects that incorporate the design for environment approach
Capstone projects	Mandatory rubric discussing the ethical implications and issues arising in the final year project

One of the lecturers interviewed gave the example of an exam question which asked students to discuss the ethics around landfilling, and “whether it is a problem or an opportunity, whether you can generate energy and actually recover things from it and turn it into a positive, or whether the negatives do outweigh that”.

Research projects are a popular method of incorporating sustainability topics in assessment. Some of the examples mentioned by lecturers revolve around presentation or written reports on the sustainable development goals. A lecturer described how the report assignment is asking students “to put the context of why the chosen goal was a challenge, and then to discuss what progress had been made so far and to critique whether that was sufficient progress, and then what environmental engineers could do in order to meet the 2030 target”. Another example of a research project asks students to analyse energy policies across a number of countries, with a focus on their impact on the adoption of bio-energy technologies “that could lead to sustainable, cyclic energy systems”.

The majority of capstone projects incorporate a mandatory rubric that requires students to include a section in their thesis where they reflect at the ethical implications and issues arising in their projects. This rubric is found to explicitly mention sustainability as one of the implications to be considered. For the programmes that do not yet have this requirement for the final year project, evaluators mentioned its absence and suggested the introduction of an ethics section.

5 Legislative coverage across the curriculum in practice

As seen in Table 4, legislative related coverage is another popular thematic area, present in 45 (54%) of the participant modules with a high contribution to outcome E. The topics mentioned in connection to the teaching and assessment of the legislative theme are national and international standards, directives, regulations, policies and legislation, CE marking, product liability, contract documents and planning requirements, intellectual property and patent law, as well as GDPR.

Table 4: Distribution of legislative related coverage across module types (n=83 modules)

Technical modules (n=36)	**Design modules (n=15)**	**Professional formation modules (n=12)**	**Capstone Projects (n=8)**	**Work Placement (n=2)**	**Business studies modules (n=6)**	**Legal studies modules (n=3)**	**TOTAL %**
13	10	8	5	2	4	3	**54%**

The inclusion of legislation related issues in engineering ethics education is seen as facilitating engineers to take a more active role in policymaking. As such, a lecturer singles out the medical profession, who "takes a role in advising the governments and in regulating, a much stronger role than the engineering profession has." Given the "massive societal challenges ahead now with climate change", one of the lecturers interviewed favours the inclusion of regulatory and legal issues in engineering ethics education to prepare "the engineering profession as a whole for stepping up to that. I guess that begins in education." This viewpoint is shared by another lecturer, who agrees with the inclusion of regulatory and legal issues in ethics education, such as "environmental directives," the "precautionary principle" and the "polluter pays principle," in order to prepare students to address the problems raised by climate change. A lecturer militates for the inclusion of legislative issues, stating that "it needs to be integrated because a lot of the ethical questions are around the edges of legal questions," while another considers that "when regulations, policies and the law are complex, and there are many grey areas, this is where ethics is very important".

The theme is incorporated through taught components such as lectures, lab demosntrations and case studies, as seen in Table 5.

Table 5 Teaching methods incorporating legislative issues

Type	**Example of content**
Lectures	National and international standards, directives, regulations, policies and legislation. CE marking. Product liability. Contract documents and planning requirements. Intellectual property and patent law. GDPR
Lab demonstrations	Health, Safety and Welfare at Work Regulations, National Rules for Electrical Installations (ETCI Regulations), European directive on operating machinery
Case studies	Whistleblowing in the context of legal requirements and protection

Some of the frequent topics included in lectures revolve around standards such as ISO2600 on social responsibility, safety standards and quality assurance standards such as ISO9000. Intellectual property is another frequent thematic topic mentioned in lectures across all engineering disciplines. Discipline specific issues are related to addressing contract documents and planning requirements in Civil Engineering, GDPR in Computer Engineering, Environmental directives in Environmental and Energy Engineering programmes. Lab demonstrations have been used to teach students about conducting engineering practice in a safe manner as to avoid workplace accidents, based on the guidelines set in the Safety, Health and Welfare at Work Act, operating machinery at work set in the 2006/42/EC Directive or for operating

electrical panels stated in the National Rules for Electrical Installations. Dilemmas related to whistleblowing has been a popular topic in the case studies employed, giving rise to discussions related to the protective measures and legislation needed.

For assessing legislative related coverage, the methods employed include exam questions, research projects, design projects and capstone projects, as seen in Table 6. A key issue emphasised by several lecturers is the importance of having assessment that encourages students to "apply legislation and standards to real life examples". This can be achieved by conducting a risk assessment of a specific product or process, preparing an invention disclosure or a SEA/EIA project in compliance with statutory and public hearings, as well as by integrating legislative requirements in the design of a product. It is also considered important to assess knowledge of various legislative stipulations, by asking students to recall their formulation in exam reports. Critical reflection is encouraged by adopting assessment methods that encourage students to evaluate a specific policy or formulation.

Table 6 Assessment methods incorporating legislative issues

Type	Example
Exam questions	Describe the hierarchy of standards used to ensure compliance with safety legislation Reflect on a specific policy Recall measures for protecting intellectual property
Risk and impact Assessment	Identify hazards as per the international standards Conduct a risk assessment of a product or process Write standard operating procedures for experimental work
Research projects (reports, presentations, posters)	Evaluate policies Preparing SEA/EIA projects for complying with statutory and public hearings Developing an invention disclosure
Design projects	Define core issues relating to intellectual property within a device design Integrate requirements based on existing standards and regulations
Capstone projects	Includes risk assessment rubric. Legislative considerations are encouraged in a contextual section.

6 SUMMARY

While we cannot say that the implementation of sustainability and legislation topics are carried in a systematic and even manner in the programmes that participated in the study, what does emerge is a desire to address ethical issues through their prism. Sustainability and legislation appear to be popular topics used to meet the accreditation outcome purporting to ethics. They also appear to be good candidates for integrating ethics across the curriculum, as they can be tailored to the technical expertize of engineering faculty and appeal to students. An issue that warrants further exploration is how we can use this desire to focus on ethics "as sustainability" or "as legislation" to broaden engineering education and more fully integrate the technical, social, legal and environmental dimensions of engineering in one comprehensive and holistic form of education ([21], [22]).

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APPLICATION OF INNOVATIVE PHYSICAL MODELS FOR THE SOLUTION OF TECHNOLOGICAL ENGINEERING PROBLEMS

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ABSTRACT

The most important trend in engineering education is the use of advanced physical models to solve technological problems.
We present two examples of such an innovative approach.
One of the common methods for treating industrial effluents in the coal industry is the use of sedimentation tanks, which are reservoirs into which water is supplied carrying particles of coal and solid rocks. The paper considers the movement of a two-phase medium under the action of gravity with an uneven distribution of the impurity concentration. Under the influence of gravity, a cloud of solid particles sinks to the bottom, and at the same time, due to the difference in concentrations, different parts of this cloud have nonzero velocities relative to each other. Precipitating, the particles engage the carrier medium in motion. As a result, the deposition of groups of particles occurs faster than individual particles. A two-phase convection model is used.
In the second example, a method for two-dimensional numerical simulation of submicron field-effect transistors with a Schottky gate is proposed, which allows one to take into account the effects of unsteady electron dynamics and to study complex carrier transport phenomena. The proposed approach allows one to take into

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account the edge effects at the drain end of the gates, which are manifested in the appearance of regions of high concentration of electric field strength, which significantly affect the nature of the motion of charge carriers.

1 INTRODUCTION

1.1 General basis and description of the presented tasks

The most important trend in engineering education is the use of advanced physical models to solve technological problems. We present two examples of such an innovative approach. Both examples are based on the use of complex physical and mathematical models of multiphase flow hydrodynamics to describe engineering problems. The unifying idea of the presented solutions is to take into account the features of the studied phenomena for the modification of generalized systems of equations of continuum mechanics.

At Tomsk State University and Tomsk State University of Control Systems and Radioelectronics, in the study of numerical methods for solving problems of continuum mechanics, special attention is paid to methods of simplifying the mathematical statement taking into account the physical features of the problems (as was done in the first example) and the application of the studied methods of continuous medium to solving problems in related areas (as was done in the second case by describing the problem of electrophysics with a hydrodynamic model).

1.2 Description of the problem of calculating the settling of the "cloud" of particles in the liquid

Currently, one of the important technological issues in the extractive industry is the task of treatment and recycling of industrial effluents. One of the common cleaning methods in the coal industry is the use of sedimentation tanks, which are reservoirs into which water is supplied carrying particles of coal and hard rock. Under the influence of gravity, the impurity settles and the liquid cleanses. To increase the efficiency of the process, it is necessary to be able to predict the movement of liquid and particles and take into account their mutual influence. In particular, this is explained by the fact that the fall time of a single coal particle is many times longer than the settling time of a group of particles of a similar size.

The paper considers the movement of a two-phase medium under the action of gravity with an uneven distribution of the impurity concentration. Under the influence of gravity, a cloud of solid particles sinks to the bottom, and at the same time, due to the difference in concentrations, different parts of this cloud have nonzero velocities relative to each other. Precipitating, the particles engage the carrier medium in motion, as shown by many experiments. As a result, the deposition of groups of particles occurs faster than individual particles. This phenomenon is taken into account in the work using the feedback mechanism. A two-phase convection model is used [1, 2]. The model is valid for particles with a diameter of 10-50 μm, the relaxation time of which is small compared with the characteristic process time.

Moreover, under the condition of sufficiently small volume concentrations of particles, the mechanism of interaction between particles is neglected.
The considered two-phase convection model is implemented to describe the deposition in the reservoir of a “cloud” of particles suspended in water. Sedimentation of inclusions causes vortex flows, which deform the shape of the aggregate of particles and cause accelerated sedimentation of the impurity.

1.3 Application of a hydrodynamic model to the study of electron gas in a Schottky transistor

GaAs-based field effect transistors (PT) are known to occupy an important place in semiconductor microwave electronics. Since its inception, submicron membranous PT based on the Schottky barrier have gained the main distribution. The use of two-dimensional structures for the manufacture of PT can increase the operating frequency and increase the power of the transistor. However, for this it is necessary to reduce the size of the shutter, which makes the approximation of a smooth channel unacceptable. Moreover, the absence of a substrate makes it necessary to take into account the effects of hot electrons in the drain gate region of the closure of depleted regions.
In this work, we propose a method for two-dimensional numerical simulation of submicron GaAs-PT with a Schottky gate based on the solution of partial differential equations, the Poisson equation, and current continuity for electrons, which allows one to take into account the effects of unsteady electron dynamics and to study complex carrier transport phenomena. The proposed approach allows one to take into account the edge effects at the drain end of the gates, which are manifested in the appearance of regions of high concentration of electric field strength, which significantly affect the nature of the motion of charge carriers.
The simplest models, which do not take into account the nonlinearity of the dependence of the electron drift velocity on the electric field strength, allow one to calculate the characteristics of the transistor up to the channel overlap, which is true only up to certain field strengths, after which the velocity of the charge carriers v saturates and remains constant, and this still happens until the channel is completely blocked. Taking into account the effects of non-linearity of the drift velocity allows us to calculate the characteristics of the transistor for any drain-source displacements up to breakdown and allows us to switch to two-dimensional modeling of a field-effect transistor.
For a uniformly doped PT, when there is no diffusion current, the current continuity equation takes on a simple form. The model describing the motion of electrons in the workspace is reduced to the equation of transfer of electron concentration and the equation for potential.

2 METHODOLOGY

2.1 Statement of the problem of settling of a "cloud" of particles

As a rule, the problems of the motion of multiphase media are solved on the basis of a model of interpenetrating continua. However, the system of equations for free

convection in a two-phase medium proposed in [1, 2], used in solving this task, has a positive feature, which consists in the absence of small quantities at the highest derivatives in the equations of motion, which makes it possible to use a faster and simpler calculation algorithm.
The aforementioned model of two-phase convection is implemented to describe the deposition of clouds in the tank from particles suspended in water. The plane problem was considered for the square in the vertical cross section of the region into which the set of particles is immersed. At the initial moment, the liquid and impurity are motionless, the “cloud” of particles has a rectangular shape.
In the equation of fluid motion, the presence of particles and their influence on the medium are taken into account through the integral characteristic — the density of the particle cloud ρ_s , which is calculated by the method of labeled particles. The interaction of the solid phase with the carrier medium is taken into account according to the Stokes law under the assumption that the impurity fragments have a spherical shape. This type of interaction is accepted as valid for both viscous and inviscid representations of the carrier medium.

2.2 Statement of the problem of electron gas motion

For a uniformly doped PT, when there is no diffusion current, the current continuity equation takes a simple form [3]. A model describing the motion of electrons in the working region under the assumption that there is no generation of charge sources and that recombination is negligible reduces to the equation of electron concentration transfer *Eq. (1)* .and the equation for the potential *Eq. (2).*

$$\frac{\partial n}{\partial t} + u\frac{\partial n}{\partial x} + v\frac{\partial n}{\partial y} = 0 \tag{1}$$

$$\nabla^2 \varphi = \frac{\rho}{\varepsilon} \tag{2}$$

here n is the electron concentration, u and v are the components of the displacement velocity, φ is the electric field potential, ρ is the charge density, ε is the dielectric constant of the medium, t – time.

The field effect transistor is schematically represented in Figure 1 by a rectangular GaAs region bounded by the metallized source and drain contacts. The drain in the Figure 1 is designated as discharge.

According to the third coordinate, the field effect transistor is considered large enough so that it is possible not to take into account edge effects. The gates are located symmetrically along the wide side of the GaAs region. The figure also shows the region of the Schottky barrier under the gate depleted in charge carriers. The depleted region expands as it approaches the drain, and when large displacements are applied between the drain and the source (or gate and source), the current flow channel is blocked on the drain side of the gate. The method proposed in the article allows one to change the concentration of charge carriers in the active region and calculate uniformly and nonuniformly doped field-effect transistors.

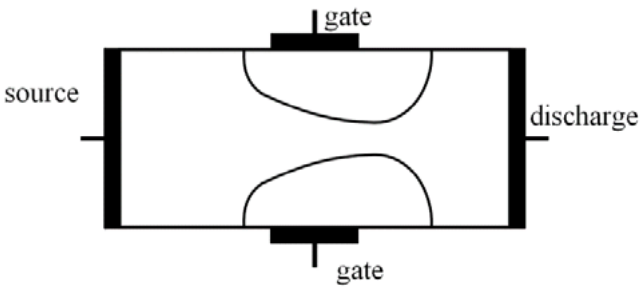

Fig. 1. Schottky Field Effect Transistor Model

3 RESULTS

3.1 Solution methods

Both problems under consideration are described by systems of partial differential equations. A more detailed presentation is given in the sources indicated in the reference.

To solve the equations, they are approximated by second-order finite differences, which makes it possible to obtain a system of algebraic equations, which is solved by standard methods

3.2 The results of the calculation of sedimentation of particles

Figure 2 shows the calculated field of fluid velocities and the arrangement of particles at various points in time. Sedimentation of inclusions causes vortex flows, which deform the shape of the aggregate of particles and cause accelerated sedimentation of the impurity. The nature of the behavior of the particle cloud is confirmed by the experimental data obtained by V.G. Khorugani [4].

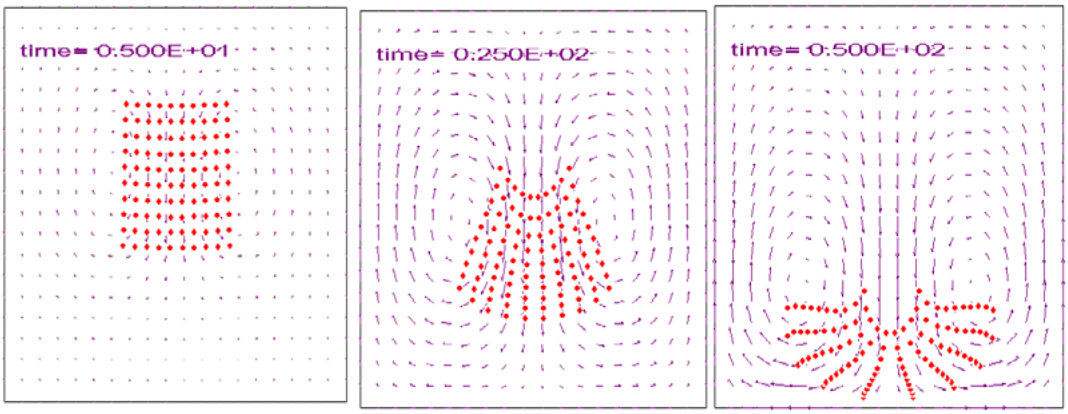

Fig. *2* Field of fluid velocities and the arrangement of particles at various points in time

Figure 3 shows the dependence of the particle cloud deposition time (t) in seconds on the particle concentration (ρ_s) for viscous (1) and inviscid (2) settings. The calculations were carried out at mass concentrations from 0.001 kg/m^3 to 0.04 kg/m^3.

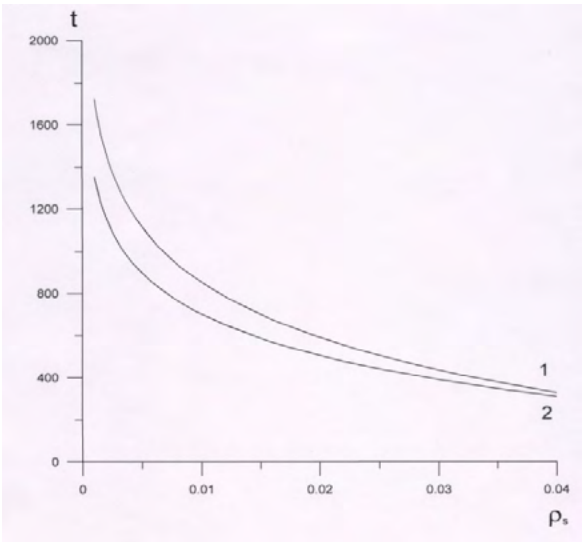

Fig. *3.* Dependence of the particle cloud deposition time (t) in seconds on the particle concentration (ρ_s):
1 – viscous settings ; 2 - inviscid settings

The results obtained for a viscous fluid are given in comparison with the results for an inviscid fluid. In a viscous medium, the deposition of particles is slower than in an inviscid medium, but with increasing concentration, the results gradually converge, which is explained by a decrease in the role of viscosity with respect to inertial forces.

Thus, taking into account the inverse effect of the aggregate of settling particles of an impurity involving the carrier medium in motion, it is possible to obtain the settling time of a “cloud” of particles significantly different from the settling time of a single particle. This is in full accordance with the data from practice

Comparison of the calculation results with similar ones performed on standard application software packages showed that the application of the proposed model can reduce the calculation time from 4 to 10 times.

Thus, the possibility of calculating by the proposed method the process of gravitational sedimentation of an impurity based on a two-phase convection model in industrial wastewater treatment plants is shown.

3.3 Results of the study of the motion of electrons

Figure 4 shows the lines of equal electron density, and figure 5 the lines of equal potentials for the drain-source displacements of 14 V, the gate-source displacements are 2.8 V. At such displacements, if we use the smooth channel approximation, the depletion regions should be overlapped and current flow is not possible. However, taking into account the effects of the nonlinearity of the drift velocity made it possible to calculate the characteristics of the PT, which are consistent with experimental data showing the presence of electron displacement from source to sink, i.e. the presence of current, as shown in Figure 4

An analysis of the potential and charge distribution showed that even at low potentials, a strong field exists at the gate and drain near the drain edge of the gate. It is established that for transistors with small geometric dimensions, the traditional approach of smooth channel approximation using the Poisson equation and the continuity condition becomes unsuitable.

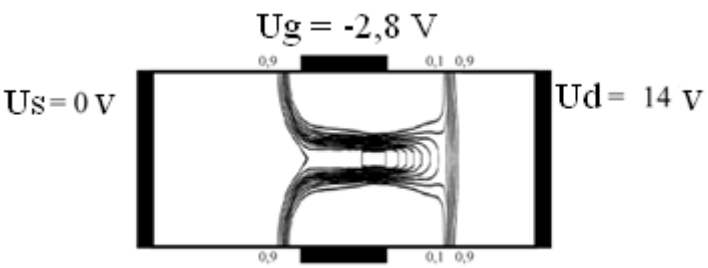

Fig. 4. Lines of equal electron density

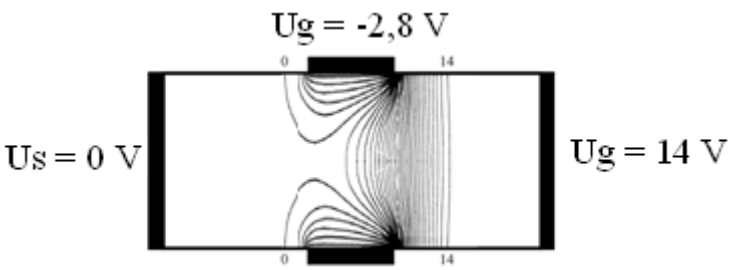

Fig. 5. Equipotential lines

The research results indicate the ability to simulate the current-voltage characteristics of field-effect transistors at a sufficient level that allows the design of devices of promising directions.

4 SUMMARY AND ACKNOWLEDGMENTS

The presented works show the relevance and need for students to study at a deep level physics, mathematics and numerical methods in the mechanics of a continuous medium. Taking into account the features of the processes under consideration allowed for the problem of settling a set of particles to significantly reduce the calculation time without losing accuracy, and to obtain data close to practical. The physical-mathematical model uses the concept of liquid concentration for a cloud of settling solid particles and allows to automatically take into account free convection and interaction of media without using complex models of interpenetrating continua. A more accurate simulation of the process of electron gas motion in a semiconductor made it possible to obtain a solution, which could not be obtained with a simple engineering approach. The representation of the electric current in a transistor in the form of a multidimensional particle flux allows the use of well-developed hydrodynamic models. It becomes possible to trace the entire process of electron movement, to determine the areas of change in their concentration and trajectory of their movement.
The solution found coincides with the operation of real transistors.
Only the use of more accurate innovative physical and mathematical models for solving engineering problems will allow us to move along the path of scientific and technological progress while preserving the ecology of our planet and rationally using natural resources.

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ENGINEERING IDENTITY IN THE SOUTH AFRICAN CONTEXT

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ABSTRACT

Understanding students' experiences is an integral part of supporting a more diverse student population within the field of engineering. Growing evidence suggests that a greater identification with the engineering profession encourages student persistence. Using identity theory, this study aims to investigate the factors that facilitate the development of engineering identity in undergraduate engineering students using a qualitative research design. Individual interviews with fifteen students in their final year of their engineering programmes provided the primary source of data. The emergent themes explain how students' make sense of their experiences and develop engineering identities as they progress through their engineering degrees. This study provides further insight on student experiences and could inform possible interventions for student retention in engineering programs.

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1 INTRODUCTION

According to Pierrakos et al. (2009), engineering departments are the first concrete contact many high school graduates have with the engineering community. While it is likely learners have interacted with media which centres on engineering or been exposed to the engineering industry through relatives, role models and job shadowing (Jawitz and Case 1998; Reed and Case 2003), tertiary education programmes are still seen as the first essential step to becoming an engineer and developing a professional identity within the engineering community.

1.1 What is an engineering identity?

First-year students start to form a narrative of "What does an engineer do?"; "Who is an engineer?" and "How do I fit into engineering?" These questions are strongly related to students' professional identity. Engineering students may assume a professional identity of student engineers who will progress to working engineers after graduation and practical training since, as students, they cannot validate themselves as professional engineers (Tonso 2006).

Professional identity has several definitions within engineering education literature with authors describing social and individual dimensions to one's professional identity (Morelock 2017; Dehing, Jochems, and Baartman 2013). The social dimension makes transparent who is and who is not a professional, visibly regulating the attributes, competencies, values and beliefs of those who define themselves in the profession; while the individual dimension deals with a person's identification with the profession (Stevens et al. 2008; Tonso 2014).

Using Tonso's (2014) description of engineering identity, the concept of how an individual perceives themselves in relation to the engineering profession, engineering identity development can thus be seen as an ongoing and complex process that students undergo during their engineering careers, where they frame and re-frame past engineering experiences (Eliot and Turns 2011). Identity theory has a relatively limited application in engineering education settings; however, identity has a strong tradition in the field of psychology.

A useful way of viewing identity is through the lens of narrative identity, a theory drawn from social psychology. McAdams (2011) proposes that people construct evolving stories of themselves to make sense of and give meaning to who they are. This dynamic narrative is a selective reconstruction of past experiences and imagined narrative futures, with an individual's identity as its product. Engineering identity can thus be seen as an internalised evolving story of the self in relation to their engineering career.

1.2 Why does engineering identity matter?

A number of studies have investigated the process of engineering identity development and the factors that affect students' engineering identity. Morelock (2017) organises these factors into constructive, detractive and directional factors. Accordingly, the constructive factors help students build stronger engineering identities and conversely, the detractive weaken students' identity construction while the directional factors affect the type of identity developed.

Detractive factors can affect students' learning, sense of belonging and persistence in engineering programs. Pierrakos (2009) and Tonso (2014) demonstrate how an individual's identification with engineering can be critical in terms of their persistence, with those who experience a weaker identification with engineering often migrating to other fields. Likewise, graduates strongly identifying as engineers after tertiary programs are more likely to remain in the engineering field, once they enter the workplace (Eliot & Turns, 2011). Additionally, factors that weaken identity construction are often focussed on issues particular to women and black people, with few interventions addressing these issues (Tonso 2014; Morelock 2017).

1.3 Research Question:

Engineering identity research provides a meaningful lens for understanding student experiences, particularly in a South African context which has a diverse, unequal society that is reflected in the student population in engineering programs at universities. From this perspective, the central research question inquires:

"What factors facilitate the development of engineering identity in undergraduate students and what is their impact on students' academic experiences within a South African context?"

2 METHODOLOGY

The methodology for this study draws on ethnographical principles. The fieldwork was conducted by a master's student in engineering education who had recently graduated with an engineering degree. The structure of the engineering programs was therefore well known to the primary researcher. The University of Cape Town (UCT) offers a four year BSc (Eng) degree with the first three years mostly theory-based and the fourth year including a major research project of the student's choice.

With this in mind, invitations to participate in the research study were sent to all final year students in mechanical, electrical, civil and chemical engineering in the last semester of their degrees. There were few responses and consequently most

participants were selected using snowball sampling practices (Creswell 2007) with participants referring others to the study. Of those who were referred, fifteen participants were selected, three students from the electrical engineering department and four students each in the remaining departments.

Participating Students	
Civil	Chantelle, Chris, Luzuko, Sinethemba
Chemical	Marina, Olivia, Scott, Sean
Electrical	Ben, French, Tshepo
Mechanical	Homer, Nosipho, Patricia, Siyamthanda

Table 1: Pseudonyms of participants from engineering departments

The primary source of data was semi-structured interviews (Creswell 2007) with interviews taking place in the third quarter of the academic year. The interview schedule was developed using McAdams' life story interview protocol (McAdams 2008) and was framed by the research question. Interview questions explored students' narrative journeys in relation to engineering and why specific event and actions had greater meaning in their engineering degrees. The interview protocol is attached as an appendix.

Narrative analysis (Polkinghorne 1995) was chosen as the preferred method of data analysis. Interviews were transcribed and then analysed using computer-assisted qualitative data analysis software (NVivo). This software offered the researchers a means of storing, retrieving, coding and sorting data. The process of coding was informed by the data analysis method.

Narrative inquiry focuses on personal stories, particularly their structure, content and themes. Plot elements of students' narratives were categorised and thematically analysed in an inductive approach (Andrews, Squire, and Tamboukou 2008). This made it highly suitable for analysing students' narratives in relation to engineering and produced interesting results.

3 FINDINGS AND DISCUSSION

Strong factors were linked to participants' engineering identity construction and several major identity themes emerged from the data. From the fifteen interviews, eight participants described fully developed engineering identities and openly labelled themselves as 'engineers' or 'student engineers '.

While seven participants indicated they would not be pursuing engineering opportunities after graduation and openly labelled themselves as not 'engineers'. Six main factors positively helped participants identify with engineering in varying degrees. These ranged from an interest in disciplinary knowledge, enjoyment in practical experience to engaging with engineering lecturers.

3.1 Constructive factors

Most participants with fully developed engineering identities such as French and Ben[2] displayed a clear interest in disciplinary knowledge. When asked about their academic experiences, these two electrical engineering students described how their outlook on learning changed from first year to their final year. They stressed the importance of gaining a deeper understanding of engineering concepts rather than just acquiring foundational knowledge for assessment purposes as they had done in their first year.

Part of their transformation was understanding the connections between different engineering courses and how they build on each other. They saw their fourth-year research projects as a natural next step in their learning and were keen to apply their acquired technical knowledge.

French and Ben also recounted their enjoyment of their fourth-year projects. Both participants emphasised the importance of using their technical and design knowledge to solve engineering design problems. While Chantelle, a civil engineering student, described how her positive vacation work experiences helped further her understanding of foundational knowledge.

She described how applying theoretical knowledge to real-world problems, helped her make connections between different engineering concepts and courses. She recounted how the experiences helped her grow personally and understand her role as an engineer better. All these experiences appeared to be crucial in helping participants identify more closely with the engineering profession, with factors falling to the left of the continuum below.

[2] All names are pseudonyms.

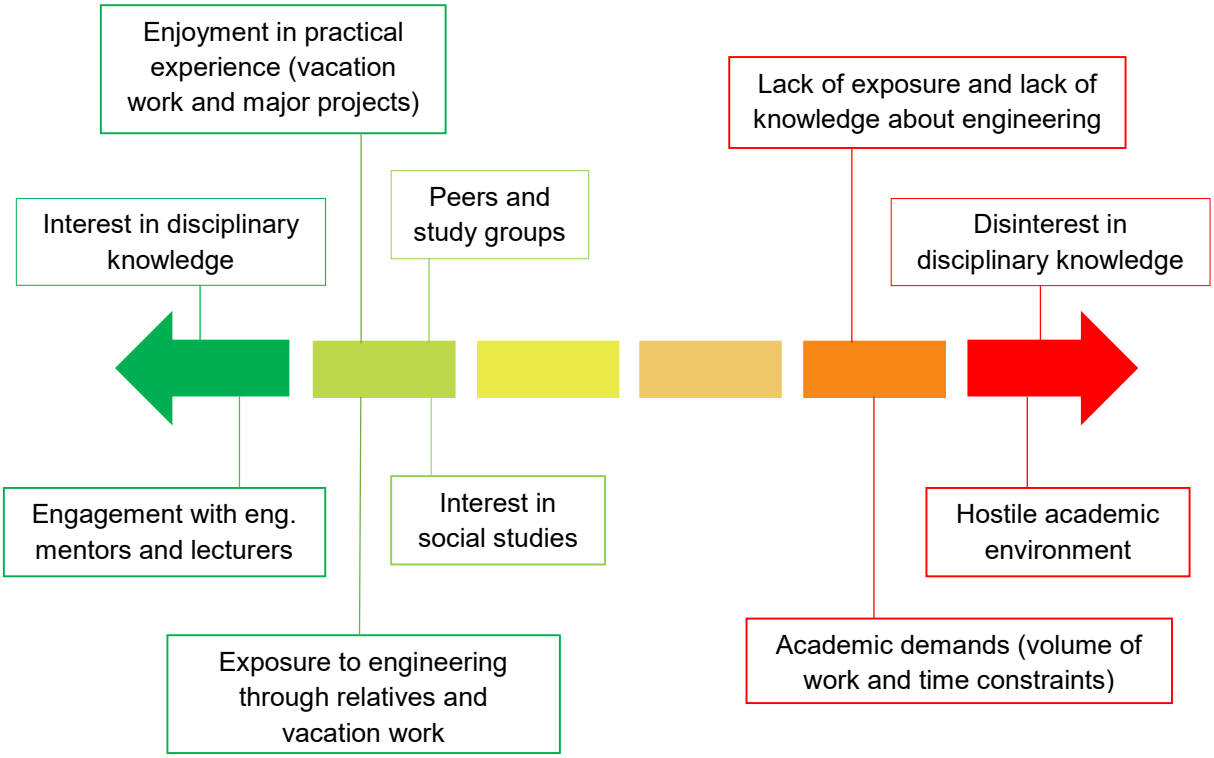

Figure 1. Continuum of factors linked to engineering identity construction.

Engineering connections were also positively linked to engineering identity construction. Sinethemba and Chris, two civil engineering students, spoke about gaining exposure to engineering industries through their bursary programmes. Whereas Chantelle had the benefit of gaining early exposure through her close relatives and learning early on she enjoyed civil engineering. Such connections proved to be important when they decided to pursue engineering. The students had a network of engineering mentors and relatives who could advise them and help them gain practical experience through vacation work opportunities.

When asked about interactions with staff, Nosipho emphasised the importance of engaging with lecturers. The mechanical engineering student described how she started asking questions and interacting with lecturers after a difficult first year. She explained how she had to overcome her inhibitions and realised that asking questions made her a better student and engineer. Seeking advice furthered her understanding of foundational knowledge and helped grow her interest and appreciation for engineering research.

Interactions with peers and study groups were mentioned by both ‘student engineers’ and ‘non-engineers’. This factor was seen as an integral part of one’s academic success. Peers and study groups were usually the first place students sought academic advice prior to consulting with lecturers. The majority of participants highlighted how fellow peers emotionally and academically supported each other through their degrees. Developing relationships with staff, mentors and peers

enhanced participants' engineering networks and ended up strengthening their identification with engineering

Another factor that was mentioned by both groups was an interest in social studies particularly those that focused on social issues and inequality. Participants with an interest in social studies showed strong social and political identities. Students with fully developed engineering identities and a social interest were motivated to pursue engineering work that benefited greater society. While this factor strengthened students' identification with engineering, it could also be classified as a directional factor which affects the type of engineering identity developed.

Most of the constructive factors are present in engineering education literature. Two emergent categories arose similar to Morelock's (2017) engineering-related experiences and engineering network. This is important as it speaks to the link between students' academic experiences and engineering identity development. Positive academic activities such as engaging with lecturers, trying to conceptually understand engineering theory and interacting with peers and study groups, resulted in further developed engineering identities. Which means engineering identity can be used as a mediator for one's academic experiences.

Another interesting finding was how an interest in social studies and a strong social identity affected engineering identity. Few studies highlight students' social or political identities impacting engineering identity (Tonso 2014; Morelock 2017) though the appearance of a social identity is understandable within the South African context. The University of Cape Town and other South African universities have faced major protests in recent years. All participants were students during the country-wide #FeesMustFall and #RhodesMustFall university protests and interviews took place just weeks after a gender-based violence protest at UCT. The fact that multiple participants spoke about how social issues impact their views of engineering, shows that engineering identities cannot be divorced from other aspects of an individual's identity.

3.2 Detractive factors

For the seven participants who openly labelled themselves as not 'engineers'. Factors that negatively impacted students' engineering identities often occurred in combination and were frequently linked to students' academic experiences. These ranged from challenging academic demands, to a disinterest in engineering knowledge, to hostile academic environments.

Unsurprisingly, most of these participants were impartial or indifferent towards disciplinary work. Homer, a mechanical engineering student, recounted how he wasn't drawn towards engineering work and would rather work within the financial sector after graduation. While Luzuko in civil engineering mentioned that though he valued the

problem-solving skills he had acquired during his degree, he would rather work in social entrepreneurship. His initial lack of exposure to engineering coupled with his academic struggles added to his disinterest in pursuing civil engineering after graduation. Whereas Rachel cited how a hostile academic environment in mechanical engineering and excessive academic demands in her degree made her wary of entering an engineering workplace. Rachel recounted how she faced gender marginalisation while working with her male peers and added that the stress of getting her degree was not worth continuing with engineering.

The identified detractive factors were unsurprising as many of them were present in engineering education literature. The fact that three of the four detractive factors are based on students' experiences within their degrees underpins the connection between engineering experiences and identity construction. Students' engineering identities can bring to light educational issues and act as a mediator for students' academic experiences.

4 CONCLUSION

While identity research offers a meaningful framework to explore multiple aspects of an individual's experience, few studies are focused on engineering identity in the Global South. In this study, fifteen interviews were conducted with final-year engineering students at a South African university to understand what factors facilitated the development of engineering identity and how they impacted on students' academic experiences. Narrative analysis revealed a range of constructive and detractive factors impacting students' engineering identity.

Most constructive factors were related to students engineering experiences (academic work, vacation work) and their network (peers, lecturers, mentors). Students' engineering identities often developed alongside their personal and social identities. These identities often informed students' engineering identity and motivated them to pursue engineering with a socially engaged focus. In contrast, detractive factors seemed to come in combinations, with negative academic experiences and disinterest in disciplinary knowledge as a popular combination. These factors dissuaded students from seeking engineering opportunities after graduation.

Overall, students with stronger engineering identities had more meaningful engineering experiences in their academic careers and had a stronger engineering network. From these findings, a number of recommendations can be made. Students should be encouraged to participate in engineering-related activities outside of the curriculum such as university engineering societies. They should be encouraged to seek out mentors and roles models, whether other students (undergraduate and postgraduate), academic staff or working engineering professionals. Lastly, further

research is needed to understand engineering identity development and its impact on students, particularly in South Africa and the Global South.

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6 APPENDIX

Interview protocol used during interviews.

Interview Protocol:

I want you to think of the interviews an exploration into your learning journey in engineering. Think of your time at university as a novel, with different chapters and scenes, with high points and low points. We are exploring your story in university and in engineering.

1. Take me back to high school and why did you choose to study engineering?
    a. Why did you choose your discipline?
    b. Were you exposed to engineering before coming to university?
    c. What were your expectations of university and your engineering academic work?
2. What was coming into university like?
    a. How was the transition from high school to university?
    b. How did things progress in first year?
    c. Could you tell me about the parts where you excelled or struggled?
3. How were the middle years? Second and third year?
    a. Were things different from first year?
    b. How did your experiences measure up to the expectations?
4. What were your interactions with peers like?
    a. Did you participate in any study groups or peer networks?
    b. How were your experiences with group work?
5. What were your interactions with staff members like?
    a. How were your lecture and tutorial experiences with staff members?
    b. Did you have any one-on-one or small group (two or three students) meetings with staff members?
6. What experiences (high and low) stand out most for you in your engineering career now that you are nearing graduation?
    a. Did it influence how you see yourself?
    b. Did it influence how you see yourself as an engineer?
7. What experience was most important to you in your engineering journey?
    a. What impact did it have on you as an engineering student?
    b. Did it influence your career decisions?
    c. Did it influence how you see yourself?
8. Is there anything you would like to add?

MECHANICAL ENGINEERING STUDENTS' PERCEPTION OF THE QUALITY OF WORK AFFORDANCES DURING WORK PLACEMENT

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ABSTRACT

The quality of work experience that is available to engineering students as part of the formal academic programme has considerable influence on their employability outcomes. Despite this, the factors and processes through which they exert their influence have not been fully understood. This paper describes a study that sought to explain what influences the quality of work affordances and how this influence is produced. The study collected qualitative data from mechanical engineering students using interviews and documents. It then analysed the data using thematic analysis and synthesis. It found that the learning environment and the industry mentor influence the quality of work affordances that students experience. It also found that interactions between industry mentor as work supervisor and teacher and an enabling learning environment tended to produce broad and meaningful work affordances. Conversely, industry mentor as work supervisor only and constraining learning environments led to the affordance of work of narrow scope. Understanding of these processes would empower universities to influence the meaningfulness of the work placement experiences of their students.

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1 INTRODUCTION

Work placement can provide students with personal knowledge of the workplace, generic skills, attitudes and behaviours that facilitate a smooth transition into employment. However, ensuring that all students who go through work placement get appropriate work experience is challenging. Rayner and Theo [1] provide many examples of what can go wrong with work placement, such as students being used as cheap labour and being assigned work that is not related to their qualification. Nevison et al. [2] explain that exposure to meaningful work is an essential factor of work placement experiences that contribute to the enhancement of students' functional capabilities. They found that the learning environment has a significant influence on the perceived meaningfulness of afforded work placement. Similarly, Kramer-Simpson [3] found that the quality and attitude of an industry mentor influence the meaningfulness of work.

Unfortunately, these two studies, and most other previous studies, consider the influence of organisational environment and industry mentor factors in isolation from each other. Therefore, it remains unclear as to how these factors interact and how their interaction might influence the quality of afforded work. Consideration of the interactions of the factors in addition to their individual influence on work affordances is essential in developing a clearer picture of the mechanism influencing the quality of work affordances. To allow for interaction of the factors, work placement needs be considered as a conceptual system. A conceptual system is "a network of multiple variables that are connected through causal relationship and expresses some sort of behaviour, which can only be characterised through observation as a whole" [4]. Work placement can be considered a system that is intended to transform students who have theoretical knowledge of engineering concepts into students who have occupational competency and self-efficacy in engineering; in other words, work-ready. This paper sought to explain how mechanical engineering students' perception of their organisational environment and industry mentor factors influence how they perceive the quality of their work affordances. Understanding this is crucial in designing and implementing work placement programs in a manner that promotes student employability.

2 METHODOLOGY

The research presented in this paper followed a qualitative multi-case study approach. This approach is appropriate for an investigation such as this that sought to explain the variables and processes influencing the quality of work affordances by drawing on the perceptions of the participants themselves

2.1 Research participants

The study collected qualitative data from thirty-four participants, mechanical engineering students from a South African university of technology who were undergoing year-long placements. Thirty-two participants were placed at companies within one province. The remaining two participants were placed in a different

province. Only two participants had previous exposure to work experience, one as a sales administrator and the other as an engineering drawing instructor.

2.2 Data collection

After obtaining institutional ethics approval, qualitative data was collected from the participants using semi-structured interviews, and from the examination of their work placement logbooks and evidence portfolios.

2.3 Data analysis

The study used a qualitative data analysis process that combined Bryman's [5] generic thematic analysis approach and the interactive data analysis process developed by Miles, Huberman and Saldana [6]. The steps that were followed in the data analysis are illustrated in *Fig.1*.

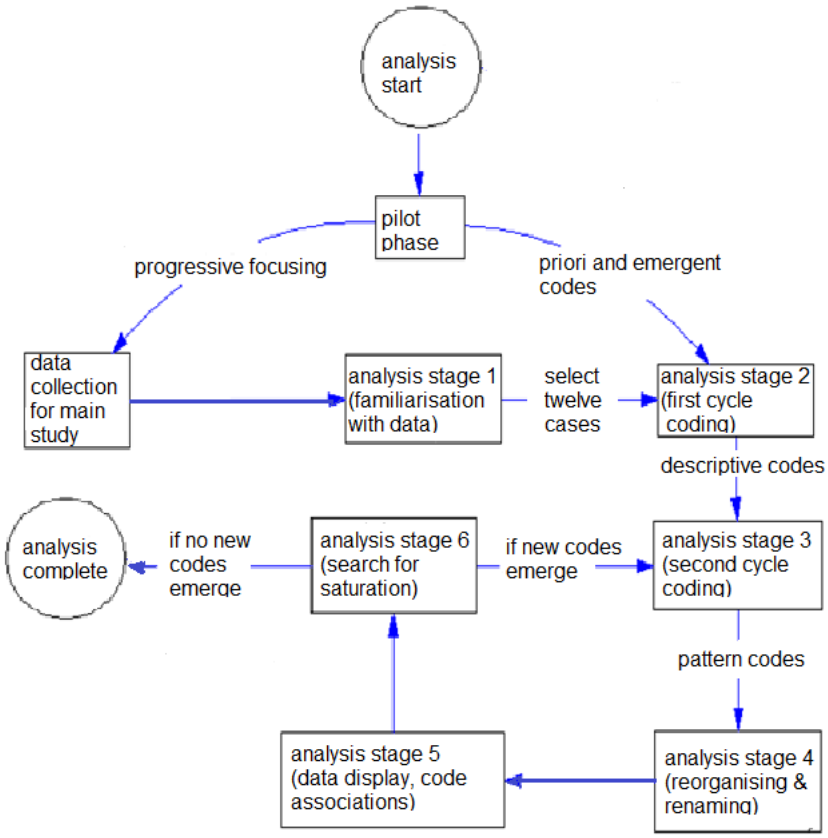

Fig. 1: Steps that were followed during qualitative data analysis

The analysis started with the thematic analysis. This was followed by thematic synthesis, which comprised intra-case and inter-case comparison using matrix coding, comparison diagrams and hierarchical charts. The thematic synthesis allowed the researcher to discover relationships between the subthemes. These were modelled using causal loop diagrams using procedures that were developed by Yearworth and White [7].

3 FINDINGS

Thematic analysis identified three themes representing aspects of work placement experiences that formed the work affordance system. Each theme had several constituent subthemes, representing various attributes. The remainder of this section presents the findings related to the three components of work affordance system.

3.1 Theme one: the learning environment

The findings show that the students categorised their experiences of their environment as either enabling or constraining. They considered their learning environment to be enabling if they had access to broad and meaningful work and close guidance. On the contrary, the students considered their learning environments to be constraining if they filled actual job positions, had access to work of narrow scope, had limited access to guidance and if their environments had a low tolerance for work errors.

The attributes of constraining environments signalled minimal allowance for activities that facilitated student learning and an inclination to structure students' work affordances to meet organisational goals. This inclination resulted in students filling actual job positions which severely constrained their learning and curtailed their exposure to task diversity. Ordinarily, this might have been beneficial, but because of their lack of work experience, most students were assigned low-skill, low-risk assignments which offered little university-practice integration.

3.2 Theme two: the industry mentor

The findings suggest that the students considered their industry mentors' actions to be the most significantly influential aspect of the learning environments. They believed that their industry mentors exercised control over access to work and participation opportunities that were available in the learning environment. An industry mentor's ability to function in this role was dependent on that mentor's capacity and availability. Mentor capacity refers to a mentor's ability to perform mentoring functions in a manner that facilitates efficacious workplace student learning. Mentor availability refers to the ease with which students might access guidance from mentors. The guidance entailed giving direction to the students about what they needed to do, allowing them to observe their co-workers in action and participating side by side with the students in work activities.

The findings showed that most high-capacity mentors were from the management echelons of the host companies. These mentors had the power to allocate meaningful work to the students. Some students reported that their mentors diverted work from themselves or other workers to their students to expose them to a diverse range of work assignments. With most high-capacity mentors, there was the challenge of availability. However, some mentors were able to compensate for their unavailability by delegating some of the mentoring responsibilities to their subordinates.

Students reported that they struggled to complete most work activities on their own. In most cases, high-availability mentors – who were often the students' immediate supervisors – were available to provide guidance. Unfortunately, with most high-availability mentors, there was the challenge of providing their protégés with a broad scope of work. These mentors did not often have the authority to assign students to other departments, even when they thought that the students would benefit from such an assignment.

Most participants spoke of their mentors in two ways: as if they were teachers or only as supervisors. These two perceived postures reflect an inherent tension that exists in workplaces. Students' recollections of the placement experiences suggested continuous contestation between learning and working, which presented itself in the mentor-to-student interactions. When the mentor was positioned as a supervisor, productivity was prioritised over learning. In contrast, when the mentor was positioned as a teacher, the students' learning was prioritised over operational gains, or at least these needs were considered together.

3.3 Theme three: quality of work affordances

The work that was available to students during work placement varied in terms of scope and meaningfulness. Some work affordances were broad and meaningful, whereas others were of narrow scope. Some students reported that they were exposed to diverse work assignments that added value to their placement company, work that would ordinarily be performed by technicians or engineers. Also, the students were exposed to non-technical work such as interacting with contractors and clients, which improved their generic skills such as problem-solving, teamwork, leading work teams and communication. Such broad exposure assisted the students to appreciate the nature of engineering practice. It also gave students confidence that they would be successful in their future employment.

Unfortunately, other students reported that they were afforded work of narrow scope that was based on operational considerations rather than their learning needs. Most of this work tended to be monotonous and of low-responsibility such as operating various production equipment, inspecting the quality of products, doing administrative work and performing artisan-level tasks. The students considered these tasks token and not aligned to their future roles as technicians. As a result, they developed low occupational self-efficacy and became worried about their work readiness. It was found that in some cases, repetition of work tasks was beneficial in that it facilitated task proficiency. Some students who were placed in a single department for the entire placement period developed high self-efficacy. These students had performed work that was of value to their placement company and which aligned to their perceived identity as future engineering practitioners.

3.4 The work affordance system

The analysis suggests that the attributes of the themes represented their variation. Thus, they were identified as variables; in total, six variables were identified. The identified variables are shown in *Table 1*.

Table 1. The variables that form the work affordance system and its outcome

System component/outcome	Variables (scale)
Learning environment	Enabling /constraining
The industry mentor	As teacher /as supervisor/ as teacher and supervisor High capacity /low capacity High availability /low availability
Quality of work affordances	Meaningful/token Broad/narrow scope

The intra-case and inter-case comparison uncovered relations among some of the variables shown in *Table 1*. Besides, associations among the learning environment, mentor capacity, mentor posture and quality of work affordances were identifiable from the student's recollections of their experiences. For example, the students believed that when their mentors positioned themselves as supervisors, their actions were directed at either ensuring that the students fulfilled some operational demand such as replacing staff who had resigned or filling positions that had arisen owing to increased work demands. They suggested that this led to their exposure to work of narrow scope. In addition, the association of mentor posture and the learning environment was reflected in how a change in learning environment produced a change in mentor posture. Thus, the mentor posture was not static. It was responsive to the prevailing environment within the workplace. In some cases, a change in workplace conditions influenced mentor posture. In this study, the most common change in workplace conditions was staff shortages due to resignations.

The study found further associations among other variables. When all the associations were mapped using qualitative systems dynamics modelling, the work affordance system shown in *Fig. 2*.

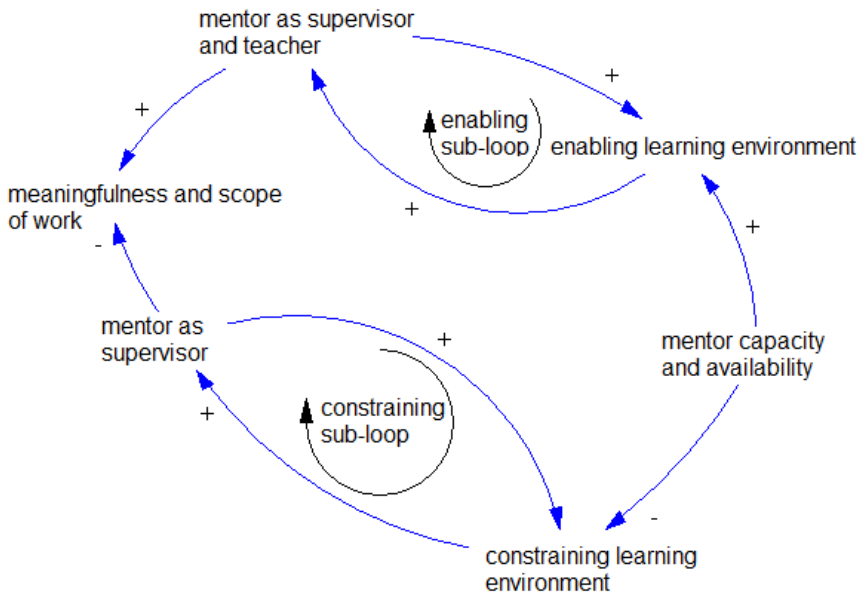

Fig. 2: The work affordance system: its variables and their associations

Fig. 2 suggests that the likelihood of an enabling learning environment increased with an increase in mentor capacity and mentor availability, i.e. a feedback loop. High mentor capacity and mentor availability facilitated an enabling learning environment. *Fig. 2* further suggests that that the persistence of the enabling learning environment depended on mentor posture. If the industry mentor adopted and continued functioning as both teacher and work supervisor, the enabling learning environment was sustained through the functioning of the enabling sub-loop. In case of a change in the industry mentor's posture to that of supervisor or teacher only, the effectiveness of the enabling learning environment was compromised.

It can be seen from *Fig. 2* that continued affordance of meaningful work was dependent on the presence of an enabling learning environment sustaining the mentor posture as both teacher and work supervisor. In contrast, *Fig 2* also suggests that limited mentor capacity and availability increases the likelihood of a constraining learning environment. It suggests that once formed, a constraining learning environment influences the industry mentor to adopt the posture of supervisor only. When this happens, the interaction of these two elements results in students being afforded work of narrow scope that do not address their learning needs.

4 DISCUSSION

This paper explored how the systemic behaviour of variables influences the quality of work affordances that are available to mechanical engineering students during work placement. It was expected that the learning environment [2], the industry mentor [3] and student characteristics [8] would form part of this system. However, the findings show that only the learning environment and industry mentors explicitly influence the

quality of work affordances and each other. This finding does not mean that student's agency is irrelevant. The findings showed that students solicited work and guidance from their industry mentors more than from any other source. By going through their industry mentors, the students used collective constructional agency to indirectly influencing the quality of work affordances [8]. For example, in Fig. 2, the return path from mentor as supervisor and teacher to enabling learning environment has elements of the students' participation in the work affordance system, even though their influence is mediated by their industry mentors.

Another issue that arose from the findings is the significance of the industry mentor's influence. The findings show that the industry mentor's ability to act as supervisor and teacher was an antecedent of meaningful work affordances. The students believed that the afforded work was meaningful if it were similar to that performed by their co-workers. They wanted their mentors to give them the responsibility to perform such tasks. However, the students needed to be provided support when it appears that they would not be able to perform these practitioner-level tasks without support. Kramer-Simpson [3] referred to this as 'contingent scaffolding', giving the students an illusion of choice and responsibility, while observing from afar to ensure that the students learn from the activities and also meet the requirements of the workplace. It was this contingent scaffolding that necessitated the additional attributes of enabling learning environments that had moderate tolerance of work errors because as novices, student performance is slow and prone to errors [9].

Effective execution of industry mentors' role as supervisor and teacher required support from co-workers. The industry mentors would not provide contingent scaffolding to their students all the time. They needed support from co-workers to discreetly observe the students and provide feedback to them on how the students were doing. This collaborates the findings by Eames and Bell [10] that suggest that work placement learning is socially situated, hence the actions of co-workers that can not be ignored. Learning during work placement requires occupational socialisation that goes beyond the industry-mentor-student interactions. Therefore, other people in the workplace need to know the reasons for and support the presence of work placement students in the workplace. This is consistent with Lave and Wenger's [11] view of learning as legitimate peripheral participation in a social community and whose success depends on the actions of their entire community.

The awareness of the significance of the industry mentor's influence on the meaningfulness of afforded work provides an opportunity for universities to influence the quality of their students' work placement experiences. Universities would provide training to new industry mentors to enable them to provide authentic work to students and support them with contingent scaffolding. Such training would also be provided to industry mentors as an intervention when work placement coordinators consider an ongoing student work placement to be going in the wrong direction. Although industry mentors training has not been tried in work placement programs

that are offered by South African universities of technology, literature from other countries suggest that the training would enhance the quality of mentoring that students receive. For instance, in their study of teacher education mentors, Lejonberg, Elstad and Christophersen [12] found that training workplace mentors would enable them to understand their roles better and to develop awareness and skills that would enable them to adopt a multi-faceted approach to their mentoring.

5 CONCLUSION

This paper explained the mechanism that determines the quality of work affordances during work placement. It showed the quality of work affordance is an outcome of dynamic interactions of factors relating to industry mentors and the learning environments. It further explained that there is a reciprocal influence between the industry mentor and the learning environment. The awareness of reciprocal influence presents an opportunity for universities to influence the quality of work affordance that is available by devising training programs for industry mentors that would enable them to adopt appropriate posture. It also suggests that it is possible, through targeted interventions, for universities to change the trajectory of work placements that seem to be going wrong by promoting appropriate mentor posture.

The findings of this study are especially relevant for work placement programs for mechanical engineering students in South Africa. However, the finding that industry mentors are crucial to the provision of meaningful work placement experiences is equally relevant to other countries with comparable higher education systems. Therefore, subsequent studies should investigate whether the systemic consideration of work affordances and the emergent outcomes about the quality thereof applies to other academic disciplines and in different economies.

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LEARNING TO LEARN: AN EVALUATION OF THE LEARNING THEORIES OF STANISLAS DEHAENE AND THEIR SUITABILITY FOR ENGINEERING EDUCATION

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1. INTRODUCTION

As most competent engineers know all too-well, successful operation of complex machinery requires deep familiarity with the manual and specifications of the machine. Unfortunately, when it comes to education, a good manual for the machine, the student, is not available. This can lead to engineering educators absolving themselves from responsibility to learn how their students learn, and to rely on tried and tested methods, which is often the 'chalk and talk' approach that they experienced in their own engineering formation, perhaps updated from chalk to smartboard. In a paper for REES 2015 [1], a survey of engineering facility in DIT revealed the following:

Twenty-five staff responded. The median number of years in engineering education was 15, with a low of 4 and a high of 30 years.

Table 1: Survey of Engineering Faculty and education interest

	Years Teaching Engineering	Education Qualification	Interest in the discipline of engineering education	Read any paper in an engineering education journal in the past year? E.g. JEE, IJEE	Read any paper in an engineering education journal in the past 5 years? E.g. JEE, IJEE	Attended an engineering education conference? E.g. SEFI
Mean	14.32	36%	64%	68%	72%	32%

It is good that a majority expressed an interest in engineering education, but disappointing that less than a third had ever attended an engineering education conference such as SEFI.

It is a pity that so many are not involved in the domain of engineering education, not least because the last twenty years has seen an enormous growth in our understanding of how the human brain learns. We are closer than ever to having that

'learning manual'. Not to use this knowledge as part of our own educational toolkit, is a wasted opportunity for both students and educators.

This paper examines closely the work of one such researcher into how the brain learns, the French cognitive neuroscientist, Stanislaus Dehaene. Dehaene is a professor at the Collège de France and, since 1989, the director of INSERM Unit 562, "Cognitive Neuroimaging". Although he originally trained as a mathematician, he changed course after reading Pierre Changeux's book, *L'Homme neuronal*. He collaborated with Changeux on computational neuronal models of human cognition. He received a doctorate in experimental psychology at the École des Hautes Études en Sciences Sociales (EHESS), Paris in 1989. Dehaene is perhaps best known for his work on numerical cognition, *La Bosse des Maths* (*The Number Sense*) in 1997. His biography from the Collège de France states:

Stanislas Dehaene's interests concern the cerebral bases of specifically human cognitive functions such as language, calculation, and reasoning. The team uses a variety of experimental methods, including mental chronometry in normal subjects, cognitive analyses of brain-lesioned patients, and brain-imaging studies with positron emission tomography, functional magnetic resonance imaging, and high-density recordings of event-related potentials. Formal models of minimal neuronal networks are also devised and simulated in an attempt to throw some links between molecular, physiological, imaging, and behavioral data. [2]

In 2020, Dehaene published *How We Learn* [3], an overview of current neurological models of learning. His analysis is particularly relevant for STEM educators as he states that the human child learns like a scientist, creating mental models of the outside world and continuously validating them.

This paper consists of two main sections, the first an overview of Dehaene's theory of learning, as described in *How We Learn*, and the second section an examination of the ways in which this theory could be applied to engineering education.

2.0 HOW WE LEARN

Dehaene begins in his Introduction by reflecting on why animals learn. In the case of a human being, the information encoded in our genes is, at 750 megabytes, simply too small to encompass not just the instructions for building and maintaining a human body, but also all the information that body would need to survive. But even for an extremely simple creature, such as a nematode worm, where it could be encoded in the genes, he argues that natural selection prefers learning:

With such a small number of neurons, the worm's behavior could have been fully pre-wired. However, it is not. The reason is that it is highly advantageous, indeed indispensable for its survival, to adapt to the specific environment in which it is born. Even two genetically identical organisms will not necessarily encounter the same ecosystem. In the case of the nematode, the ability to quickly adjust its behavior to the density, chemistry, and temperature of the place in which it lands allows it to be more efficient. [4]

Dehaene goes on to redefine *homo sapiens* as *homo docens*, the learning animal. It is this quality that elevates humans to the apex of the animal kingdom:

If I had to sum up, in one word, the singular talents of our species, I would answer with "learning." We are not simply Homo sapiens, but Homo docens—the species

that teaches itself. Most of what we know about the world was not given to us by our genes: we had to learn it from our environment or from those around us. No other animal has managed to change its ecological niche so radically, moving from the African savanna to deserts, mountains, islands, polar ice caps, cave dwellings, cities, and even outer space, all within a few thousand years. Learning has fueled it all. From making fire and designing stone tools to agriculture, exploration, and atomic fission, the story of humanity is one of constant self-reinvention. At the root of all these accomplishments lies one secret: the extraordinary ability of our brain to formulate hypotheses and select those that fit with our environment…

In our species, the contribution of learning is particularly large since our childhood extends over many more years than it does for other mammals. And because we possess a unique knack for language and mathematics, our learning device is able to navigate vast spaces of hypotheses that recombine into potentially infinite sets—even if they are always grounded in fixed and invariable foundations inherited from our evolution.

The tragedy for Dehaene is that so much is now known about the learning algorithms that the human brain has devolved over millions of years of evolution, but most educators are not consciously aware of these, and proceed to teach intuitively, a methodology that is at best hit and miss. We have the knowledge:

Thirty years of research, at the boundaries of computer science, neurobiology, and cognitive psychology, have largely elucidated the algorithms that our brain uses, the circuits involved, the factors that modulate their efficacy, and the reasons why they are uniquely efficient in humans. [4]

One example he gives is the excellent website provided by the British Educational Endowment Foundation (EEF). The EEF website lists and describes many different teaching strategies and their proven efficacy. [5] What distinguishes this site from many others it that it is evidence based, relying on a meta-analysis of many educational research papers. The strategy that scores highest on this website is quite simple: feedback, which it summarises as ‘high impact for low-cost’, based on moderate evidence.

This website is key to understanding Dehaene’s mission: educators need to know how students learn, and apply proven strategies that further that aim. Experience and intuition are just not enough.

Dehaene identifies four pillars of learning:

focused attention, active engagement, error feedback, and a cycle of daily rehearsal and nightly consolidation [4]

The first pillar, attention, is an essential survival strategy. Animals that are prey, pay very close attention to sights and sounds around them, as failure to hear the big cat making his approach can, and will, prove fatal. Humans are long removed from the plains of Africa, where a naked ape with very few natural defences had to pay attention or die. As most educators know all too well, attention is a very scarce commodity in the classroom. We are the first generation of educators who have to compete with smartphones for our students’ attention! But if our students are not paying attention during a lecture, they will learn very little. Or as Dehaene puts it in terms of the brains functioning:

With conscious attention, the discharges of the sensory and conceptual neurons that code for an object are massively amplified and prolonged, and their messages propagate into the prefrontal cortex, where whole populations of neurons ignite and fire for a long time, well beyond the original duration of the image. Such a strong surge of neural firing is exactly what synapses need in order to change their strength—what neuroscientists call "long-term potentiation." When a pupil pays conscious attention to, say, a foreign-language word that the teacher has just introduced, she allows that word to deeply propagate into her cortical circuits, all the way into the prefrontal cortex. As a result, that word has a much better chance of being remembered. Unconscious or unattended words remain largely confined to the brain's sensory circuits, never getting a chance to reach the deeper lexical and conceptual representations that support comprehension and semantic memory. [6]

However, Dehaene doesn't give up the battle for students' attention easily. Recognizing that video games grab attention very well, his lab has developed a number of video games to teach mathematics!

Dehaene's second pillar is active engagement. As he puts it succinctly, passive organisms do not learn:

To learn, our brain must first form a hypothetical mental model of the outside world, which it then projects onto its environment and puts to a test by comparing its predictions to what it receives from the senses. This algorithm implies an active, engaged, and attentive posture. Motivation is essential: we learn well only if we have a clear goal and we fully commit to reaching it. [7]

This attention affects the memory. Depth processing of word lists leads to better recall, e.g. if one group of subjects are asked which of 60 words are uppercase, and the other group, which of them are animal names, the subjects who had to think about animals recalled more of the 60 words.

The third pillar is error correction. This chapter begins by quoting Theodre Roosevelt, "The only man who never makes a mistake is the man who never does anything" [8] He makes a clear statement about the centrality of feedback: "it would be practically impossible to progress if we did not start off by failing. Errors always recede as long as we receive feedback that tells us how to improve. This is why error feedback is the third pillar of learning, and one of the most influential educational parameters: the quality and accuracy of the feedback we receive determines how quickly we learn." [8]

That feedback need not be external. Recall that the brain functions as a scientific modeller: if the expected input does not arrive, the brain adjusts its internal model. A key part of this adjustment comes from the feeling of surprise: the person expected x, but is surprised to get y!

The fourth pillar is consolidation: "which happens in all domains: a shift from slow, conscious, and effortful processing to fast, unconscious, and automatic expertise. Our brains never stop learning. Even when a skill is mastered, we continue to overlearn it." [9]

But how does the human brain consolidate? Dehaene's reveals the importance of sleep in learning, an aspect of sleep only discovered in the last three decades:

…learning is much more efficient when done at regular intervals: rather than cramming an entire lesson into one day, we are better off spreading out the learning.

The reason is simple: every night, our brain consolidates what it has learned during the day. This is one of the most important neuroscience discoveries of the last thirty years: sleep is not just a period of inactivity or a garbage collection of the waste products that the brain accumulated while we were awake. Quite the contrary: while we sleep, our brain remains active; it runs a specific algorithm that replays the important events it recorded during the previous day and gradually transfers them into a more efficient compartment of our memory. [10]

This is a very important discovery, but unfortunately it presents great challenges to university educators: how to persuade students to get a good night's sleep!

3.0 HOW CAN WE LEARN FROM HOW WE LEARN?

Julius Caesar begins his account of his nine year campaign against the Gauls with the geographic phrase, Gallia est omnis divisa in partes tres [11], Gaul as a whole is divided into three parts.

There are many challenges for engineering educators in Dehaene's work. Each of the pillars provides a way to improve students' learning, but none of them are easy.

The first pillar, attention, is difficult in an era of smart phones. It is also very difficult to measure, as a student looking at a lecturer, or a screen, could easily be daydreaming.

In the Handbook of Attention [12], Olney et al, have a chapter, Attention in Educational Contexts: The Role of the Learning Task in Guiding Attention, in which they suggest that the learning attention is determined by the task, which they rate as follows:

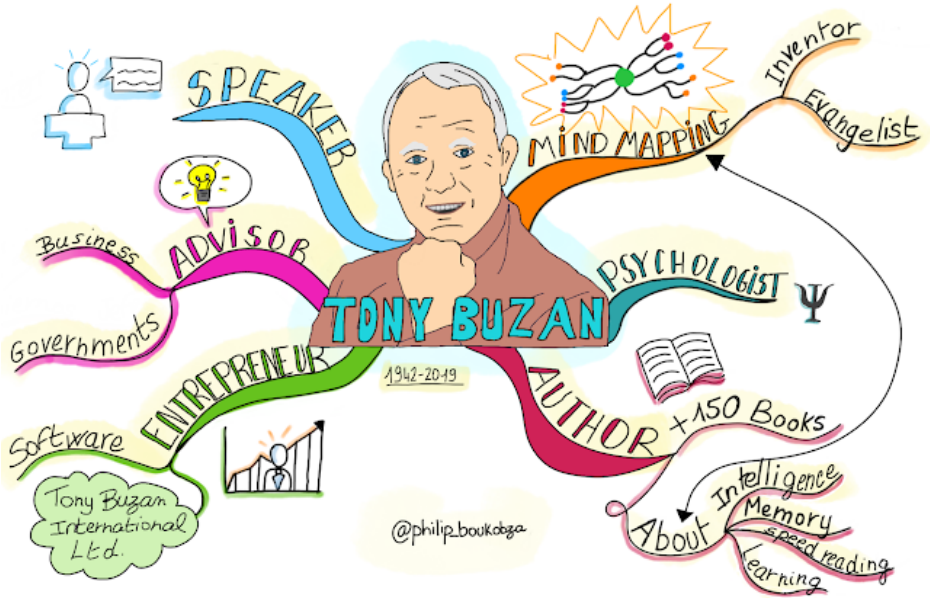
"the Interactive–Constructive–Active–Passive (ICAP) hypothesis predicts that task type (as defined by overt behaviours) will largely determine learning outcomes and rank orders the effectiveness of these activities as I ≥ C ≥ A ≥ P"

In this model, P, passive, is defined as simply listening to a lecture, live or recorded. A, active, is note taking, c, constructive, is having to sumarise, or explain the notes taken down.

I, or interactive, is when there is dialogue between student and educator. For obvious reasons, this is a small component of most lectures in large groups, due to the time constraints.

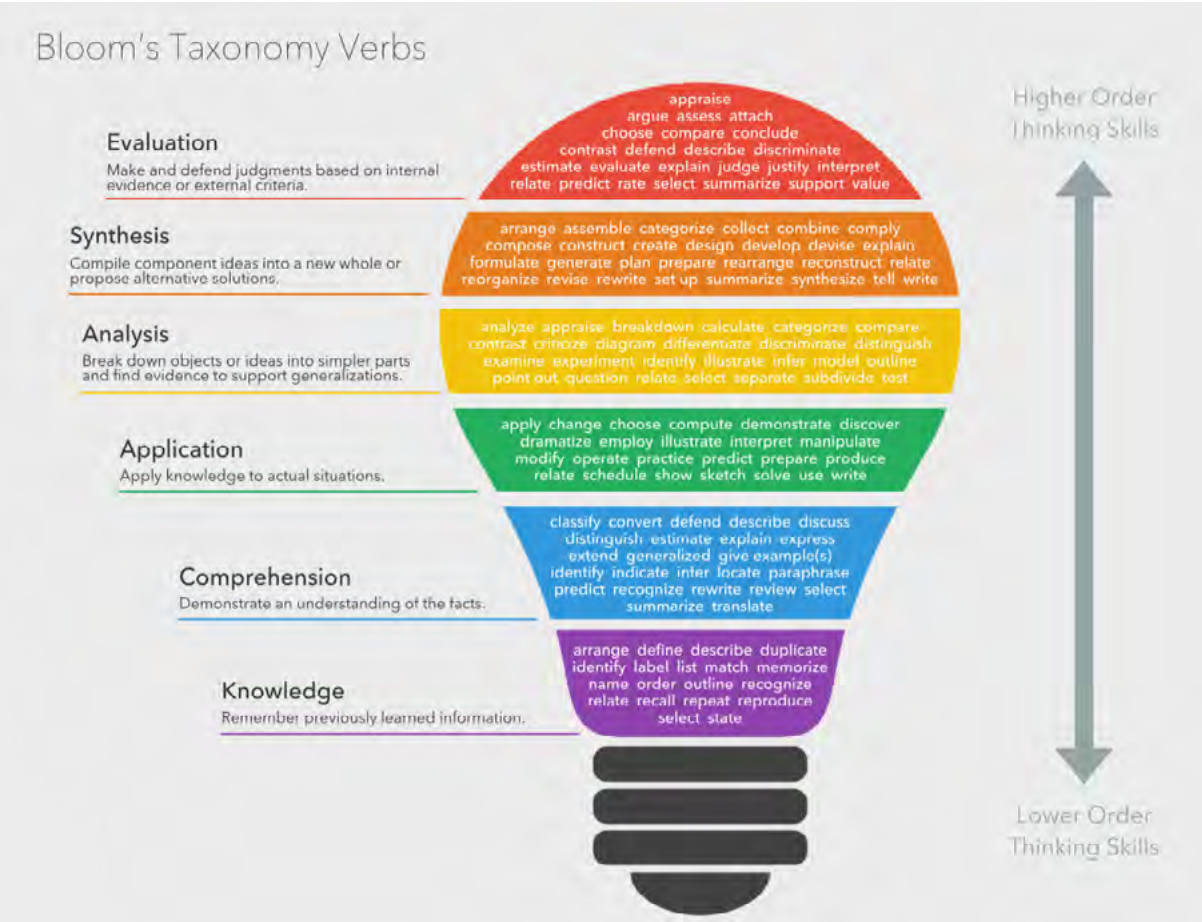
The best strategy within normal resources, is to get students to C-type activities, perhaps by using Tony Buzan's Mind Maps [13]. This is a technique of visually representing the links in a document or lecture. Students could be assessed on the quality of their Mind Maps, covering different topics, such as Heat transfer.

Figure 1: Mind Map of the late Tony Buzan's career [14]



Another way of looking at the attention-learning issue, is in the context of Benjamin Bloom's Taxonomy, where the aim is to get the students to move to higher cognitive activity, which in itself forces the brain to pay attention.

Figure 2: Bloom's Cognitive taxonomy [15]



Creating Mind Maps, at the very least, moves the learning activity up to Analysis and Synthesis.

Another approach is to meet students in their milieu. Dehaene's labs write games that aid the learning of mathematics. Is it possible for engineering educators to write apps that will grab and hold students' attention, whilst teaching core concepts? This would require a lot of resources, and cross institution collaboration, but could prove very worthwhile.

Active engagement is an area that has been tackled in educational research for a number of years. One such method is the flipped classroom, where students have to take the active role of the teacher. Australian educators Anne Gardner and Keith Willey have written extensively on this topic, and have presented papers at REES and SEFI on the topic. [16]

Another approach to active learning is open ended problems, an area developed by, amongst other, Louis Bucciarelli of MIT. Following on from Professor Bucciarelli's visit to TU Dublin in 2009, a number of projects have been undertaken in this area and reported at SEFI 2013 [17] and CISPEE 2018 [18]

Consolidation is a difficult issue, as it involves students getting regular sleep. But it also imposes constraints on academics as well. Students need to take in bite-sized pieces of information and digest it, over 8-hours of slumber. This strongly suggests that lectures should also be bite-sized, and those such as an unnamed Head of

Department who thought a 3-hour calculus lecture on a Monday afternoon was a really neat idea, should think again. Timetables must reflect human attention span, and also, consolidation span.

Dehaene's third pillar is perhaps the most interesting for engineering educators. His insight is that the human brain makes models of the world, that it successively refines by error-correction. This is, of course, the way in which science and engineering proceed. Why not make that relationship explicit? A first-year module on how both babies and scientists create and refine models, should help students grasp the modus operandi of science and engineering, and give them a life-long appreciation of models and their limitations.

There are so many ways to do this. Teaching by examples is one: The failure of the Tacoma narrows bridge in 1940, could be presented not as a failure of the design model, but of the limitations of the model, which did not include aero-elastic flutter. Subsequent models did, because engineering, like science, learns only from failure.

Models and their limitations are also behind our daily decision making. April 2020 is the 50th anniversary of the Apollo 13 accident, which nearly led to the loss of the crew. Although NASA likes to focus on the successful rescue, it rarely mentions the poor decision making that led to the accident. Chief among them was the launch engineer's ignoring of a problem with the liquid oxygen tank on fuel cell 2 in the service module. His model of the fuel cell was incomplete, being unaware that the heating circuit was designed to run on 28 V, but was running on 65 V. Using the heater to empty the faulty tank in pre-launch tests burnt the cables, leading to a spark two days after launch.

This leads to one of Dehaene's central ideas: meta-cognition leads to better learning, and better results. Too much of human activity is done on auto-pilot. Reflection, or meta-cognition, is a vital skill for all, but especially engineers. It can, and should, be explicitly taught.

A final lesson for engineering education: Mindset. Dehaene discusses the work of Carol Dweck, the Stanford Psychologist, who has spent over 25 years examining why some students learn and others don't. Dweck identifies two mindsets, fixed and growth. Fixed minds make little effort, relying on their ability. If their ability is not enough, they quit, usually blaming someone or something for their failure.

Growth mindset people know they have to work. They accept failure along the way as a challenge, a lesson, not a reason to give up. [19]

The application of Mindset to engineering education has been examined by the TU Dublin team, for example at SEFI 2019. [20] As Carol Dweck's work shows, and as the 2019 SEFI paper shows with regard to engineering, this is a skill that can be taught, and does lead to an improvement in students' learning.

4.0 CONCLUSION

In the aftermath of the Fukushima disaster, careful monitoring of the radiation levels at the site was essential for the health and safety of the Tepco workers trying to deal with six damaged nuclear reactors. Fortunately, recorded levels were consistently around the 100 mSv/hr level, high, but not too high. Unfortunately, they were too consistent. Always and everywhere around the plant, levels were 100 mSv/hr. When, after some months the monitoring team actually read the manuals, they discovered

that the instruments that they were using had a maximum reading of… 100 mSv/hr. They were designed for normal plant operation, not reactors with exposed cores.

The failure of engineering educators to read the manual, in other words to better understand how students learn, is not as serious as miss-reading radiation levels, both from a professional and an ethical point of view. However, the world needs more engineers, and if we can facilitate this by aligning our teaching methods with the brain's learning algorithms, then we will be doing a better job, for ourselves, our students, and the world.

It would be good if an organisation such as SEFI would undertake to produce a website, similar to the EEF's, with information on specific learning strategies for engineering education, backed by solid research evidence.

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REFLECTING ON A LEARNING COMMUNITY IN ENGINEERING: IMPACT ON INDIVIDUALS AND THEIR TEACHING

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ABSTRACT

In this contribution, the authors who are all members of the same Learning Community, collaborated to explore the impact of that learning community one year after its formation. We are especially keen to determine the impact, if any, that the learning community has had on our programmes and teaching practice. Given the small group that is involved and the subjective nature of the topic, we have selected a qualitative approach to evaluate impact. The data collected involved a set of documents, module descriptors, produced by the group over the past year and a narrative response to series of open-ended questions. The limitation of the narrative response is that it reveals participants subjective view of the impact of the learning community on their own professional development. The role of the document analysis is to ascertain whether these beliefs translated into action and whether participants modified the modules that they teach via our formal module descriptor document. The results identify that participation in the Learning Community resulted in a significant impact on programme development. Specifically, while participants only represent 39% of the teaching staff within the Department, they contributed over 70% of the changes to module learning outcomes that focused on important graduate attributes and without this contribution the Department would have been unable to transform programmes to the desired extent. Overall then, the learning community was impactful for this group of staff, but the impact on student learning has yet to be established.

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1 INTRODUCTION

Higher education is experiencing unprecedented changes as a result of its massification, increasingly diverse student body, funding challenges, changed conceptions of what it means to learn, greater expectations around quality and accountability from various stakeholders and expectations of "value for money" from those that pay. As a response to some of these expectations and demands, nations and institutions have turned to the professional development of those that teach within higher education settings. While traditional approaches such as seminars and workshops are widely used, other approaches such as Learning Communities would appear to be under-utilised. Moreover, there is much uncertainty regarding the effectiveness of different approaches. In this paper, we discuss the potential of Learning Communities as an effective means of professional development and evaluate the impact of a Learning Community which we are all currently participating in.

2 PROFESSIONAL DEVELOPMENT IN HIGHER EDUCATION

2.1 Evidence of impact & high impact professional development

Professional development within higher education general seeks to have an impact on teacher's *ways of thinking* or *ways of acting* and a consequential effect on students learning. Within higher education, *ways of thinking* is often associated with the constructivist philosophy [1] while desirable *ways of acting* are aligned with student or learner-centred teaching strategies [2]. A general, desirable impact on student learning is to encourage a deep approach to learning or to foster understanding [3] while specific impacts focus on measuring changes in learning outcomes. Within the educational literature, traditional forms of teacher professional development such as seminars, workshops and conferences are heavily criticised because there is little evidence that they result in these impacts on teachers or students [4]. This limited impact, it is argued, is largely due to the nature of these events which are short-term and sporadic in time and encourage teachers to be largely passive. In contrast, features of high-quality (impactful) professional development activities involve actively engaging teachers, over a sustained duration and involve a number of teachers from the same school or department [5]. The review compiled by [5] also suggests that professional development activity that focuses on the discipline and ways of teaching and learning within that discipline, and activities that are coherent with local or national policies are more likely to be impactful. In their review of instructional development in higher education, [6] also found evidence that instructional development interventions which extend over time are ore impactful compared with one-time events and that more-traditional formats (seminars, workshops, short courses, etc) had less impact that alternative formats (e.g. peer learning). In related work, [7] characterised and explored the strategies that are used to promote change in undergraduate instructional practices in STEM courses. Their review identified that effective strategies involve long-term interventions; seeks to change the beliefs of the individuals involved; and recognises

a college or university as a complex system and that effective strategies are compatible with this system [7].

2.2 Learning communities definition and types

A faculty or academic learning community is a special type of community of practice that originated in the USA at Miami University in the late 1970s. A Learning Community has been defined as "a cross-disciplinary community of 8-12 faculty (and, sometimes, professional staff and graduate students) engaged in an active, collaborative, yearlong curriculum focused on enhancing and assessing undergraduate learning with frequent activities that promote learning, development, SoTL, and community" [8]. Learning communities are often categorised as cohort-based if the community is drawn from a specific category of staff e.g. part-time staff or early-career staff or topic-based if the community was formed to address or enhance a particular issue or opportunity e.g. learning technology. Participation is voluntary and often accompanied by some incentive e.g. a grant that can be used for teaching or research purposes. [9] provides good examples of a variety of engineering learning communities including topic-based ones that focused on the flipped classroom and cohort-based ones that supported first-year faculty. Another good example is the eight-month long topic-based faculty learning community, reported in [10], who's goal was to increase both persistence and performance of under-represented students (e.g. females) in key STEM courses.

Table 1. Learning Communities as Effective forms of Professional Development

For professional development to be impactful it should	Specific characteristics of Learning Communities.
extend over time, [5]–[7]	They exist for a semester, year or longer
involve active participation, [5] [6]	Individuals are expected to engage in some specific project
involve community participation [5]	Involve 6 – 12 participants
be discipline-specific [5]	Are often discipline-based
take into account the complexity of the social context, [5], [7]	Often are local and informal in nature

Table 1 compares specific characteristics of faculty learning communities with features of impactful professional development as identified by [5]–[7] and from this comparison it is evident that faculty learning communities have the potential to impact on teaching and learning in a significant way. Some studies have evidenced this. The largest such study to date, [8] reported that this type of professional development resulted in changes in teachers beliefs and attitudes about teaching as well as improvements in student learning. However, this data was collected using a self-reported questionnaire and there was no direct measure of staff or student

learning. Studies that adopted a more rigorous evaluation support these findings, though these studies tend to be very small in nature. In [10] the authors report that 23 of the 27 projects (85%) analyzed produced “small and measurable” results, which was defined as achieving at least a 2% increase in grades, retention, improved attitudes, or STEM interest. More than half of the projects (67%) resulted in a 5% or greater increase in one or more of these measures. In a study that focused on enhancing Latino student success, participants reported increased awareness and understanding of teaching, learning and advising a culturally diverse student body as well as reporting changes to courses and assignments to make both more inclusive [11]. While this data was gathered from self-reported questionnaires, the open-ended nature of the data provided opportunities for participants to provide examples to justify or illustrate impact.

2.3 Contribution of this paper

While attempts to evaluate the impact of professional development have been ongoing for a long time, much of this evaluation is heavily criticised as only relying on self-reports from participants [6]. For example, [7] report than only “only 21% of articles that studied implementation of a change strategy were categorized as presenting strong evidence to support claims of success or failure of the strategy”. The potential problem with this self-reported data is aptly illustrated in a study reported by [12] which showed a clear disconnect between faculty’s perceptions of their teaching (documented through a self-reported questionnaire) and their actual practices (documented through an analysis of recordings of actual practice). Hence the professional development discourse has argued for more rigorous and varied approaches to evaluate the impact of these activities within higher education settings. Given the small group that is involved and the subjective nature of the topic, we have adopted a qualitative approach to evaluate impact. Our primary data is a set of documents, module descriptors, produced by the group over the past year. These documents were then analysed to identify changes to those module descriptors that arose as a result of participating in the learning community. As these are formally approved course descriptions they document either actualized or planned changes to modules and hence represent much stronger evidence than simple self-reported questionnaire data. This analysis is then used to evidence the impact that the learning community has had on our Department to date.

3 METHODOLOGY

3.1 Research Question

Following on from the literature review of the previous section, the specific research question explored was whether participation in a topic-based engineering learning community had an impact on the Department (programmes and individual staff) and to assess the extent of that impact.

3.2 Research Method

This research adopted a mixed methods approach which is consistent with the pragmatic research question posed [13]. The primary research method is a content

analysis of existing documents. These documents are the formal *module descriptors* that are used to define the courses that comprise programmes within our institution. Significant changes to these imply changes to teaching, learning or assessment activity within those modules. We elected to focus on analysing changes to module learning outcomes, as these represent the most significant part of these documents. Hence the analysis consisted of counting the number of module learning outcomes that changed over this period, categorising the nature of this change and identifying whether the change originated from a participant of the learning community or otherwise. This analysis intends to capture significant changes to teaching practices by participants of the learning community relative to others in the department. This data was then supported by reflections from individual participants of the learning community. These reflections were in response to three open-ended questions and were thematically analysed. Convergence of findings lends a certain confidence to the findings and adds to the validity and reliability of the research [13]

3.3 Participants

In January 2019, the Teaching and Learning Unit launched an initiative to support and recognise Learning Communities within our institute. The authors responded to this initiative and in February we were informed that our application was successful and that we were formally recognised as one of 13 Learning Communities within the institute. The stated objectives of our Learning Community are to
1) to enhance the programmes that we teach on by considering how key graduate competencies e.g. writing, teamwork can be integrated throughout those programmes; 2) to support the professional development of staff; 3) to research our teaching practice. Eight staff members were involved in the original application, one has since left the Department. Our Department has 18 full-time academic staff with predominantly teaching roles so this Learning Community represents 39% of the academic teaching staff within our Department. To date we have typically met for one hour every second week over the course of each semester. During the first year, the focus of activity was to plan a revised curriculum that would achieve the first objective. As a starting point we focused on three key graduate competences – writing, teamwork and ethical responsibility – as collectively we felt that our existing programmes did not develop these competencies as well as they could or should. Rather than create specific writing, teamwork or ethics modules, our approach was to integrate those skills and attributes into existing technical modules across the programme from first to fourth year. This approach mirrors that advocated by the CDIO initiative [14]. This semester our focus shifted to how we might implement or realise some of those planned changes, various strategies were being piloted and participants were encouraged and supported to consider documenting and researching some of this activity. However, COVID19 interrupted much of this planned work as the institute was formally closed mid-way through our teaching semester.

3.4 Data Collection

The primary data collected consists of a set of module descriptors for two four year programmes that this Department is responsible for – a B.Eng (Hons) in Electrical Engineering and a B.Eng. (Hons) in Electronic Engineering. Each programme consists of eight semesters. On average six, five ECTS credit modules form each semester so, on average, each programme consists of 48 modules. Some modules are serviced in from other Departments e.g. the Department of Mathematics and those modules were not considered in this analysis. The majority of currently approved modules were validated in 2015 and are publically available (https://courses.cit.ie/). Both programmes are currently being reviewed with all modules having being revised or updated and are currently being submitted for approval to the central unit responsible for Academic Quality. Hence the data that was collected consisted of 88 currently approved modules and the 82 revised modules (some elective modules were removed as part of the review). These were then compared to identify changes, and analysed to categorise the nature of that change. To complement this, participants contributed to an on-line text and were asked to respond to three open ended questions. These questions are presented in Appendix I.

3.5 Data Analysis

Module descriptors were analysed by identifying Learning Outcomes that had changed between the currently approved module descriptors and the revised module descriptors. We focused on Learning Outcomes as these represent significant changes to the module. Within our institution, it is recommended that all module descriptor documents contain between 4 – 6 learning outcomes. Hence a change to one or more of these can represent a substantial change in that module – which would then be reflected in changes to indicative content or assessment practices. Only significant changes to module learning outcomes were considered where “significant” was interpreted to mean a new learning outcome added or that the learning outcome was changed to the extent that new content would need to be included to address it. Minor changes to learning outcomes e.g. revisions to clarify the meaning were not counted and any other changes to the module descriptor document were also not recorded. These significant changes to learning outcomes were counted. They were also categorised as predominantly reflecting a development of content or a development of a graduate attribute. In our view the development of a graduate attribute (e.g. incorporating teamwork) is a more challenging change to realise and is representative of more professional development. This categorisation also helps to directly evidence the impact of this Learning Community. Finally, the changes were also categorised as either originating from one of the seven participants of this Learning Community or from the remaining 11 staff members. Data from the open-ended questionnaires was thematically analysed based on the approach advocated in [15].

4 RESULTS & DISCUSSION

4.1 Impact on Programme

Tables 2 and 3 summarise the scope of the work while table 4 presents the main results. In table 2 and 3, the column *"no of modules analysed"* represents the number of modules on both of the existing and revised programmes that are taught by staff within our department. This includes both mandatory and elective modules and excludes "service-in" modules e.g. from the Dept. of Mathematics. The total number of learning outcomes (LO's) is also documented so that the changes recorded in table 4 can be placed in some sort of context. The number of modules analysed in the currently approved programme and revised Electrical Engineering programme are not the same as a 15 credit Work Placement module was added (this is counted as a single module) and a number of elective modules were removed from this programme.

Table 2. Analysis metrics for B.Eng. (Hons) in Electrical Engineering

Currently Approved Programme		Revised Programme	
No of Modules Analysed	Total Number of LO's Analysed	No of Modules Analysed	Total Number of LO's Analysed
46	229	40	222

Table 3. Analysis metrics for B.Eng. (Hons) in Electronic Engineering

Currently Approved Programme		Revised Programme	
No of Modules Analysed	Total Number of LO's Analysed	No of Modules Analysed	Total Number of LO's Analysed
42	211	42	225

Table 4. Evidence of Impact

B.Eng. (Hons) in _	Electronic Engineering	Electrical Engineering
Total number of content focused learning outcomes changed	25	34
Total number of graduate attribute type learning outcomes changed	39	40
% of content-focused learning outcomes from LC participants	28%	44%
% of graduate attribute type learning outcomes from LC participants	62%	83%

Approximately 30% of the learning outcomes of both programmes changed during this current review. Approximately 36% of the discipline-specific content focused learning outcomes were generated by participants from this Learning Community. This

contribution is largely consistent with the size of the Learning Community which represents 39% of the Departments teaching staff. However, participants from this Learning Community contributed over 70% of the learning outcomes that were focused on graduate attributes. In the majority, these learning outcomes related to the development of writing or teamwork skills and ethical attributes. In the context of these important learning outcomes, the Learning Community has punched above its weight. An alternative way of looking at it is, in the absence of this Learning Community, the Department might have only generated ~17 new graduate-attribute type learning outcomes for each programme and largely failed in its objective to enhance both programmes.

4.2 Impact on Individuals

While Table 4 evidences the impact of the Learning Community on the programmes within this Department it could be argued that these revisions largely represent a plan that does not evidence a direct impact on teachers, teaching or learning. Reflections from participants help to support the argument that participating in the Learning Community has had an impact on *how they think* and *how they teach*. For example, one participant discussed how they have been struggling with a module that was particularly heavy with theory and mathematical concepts. The individual commented on how they had re-designed the module, including the assessment strategy to "make the module more project based. The emphasis will be on learning-by-doing, and will hopefully lead to a more enjoyable module and a deeper learning of the topic. I also hope the module will give learners more confidence and foster independent thinking". A second participant reflected on how, in the past "when trying to improve a module, I focused primarily on *what* was being taught and rarely *how* it was being taught (italics in the original)" but how the Learning Community "discussions really emphasised the importance of engaging the students to really think about the material". This has resulted in a change of focus with "increased design work – where students must really apply what they've learned. I'm delighted with the immediate impact on the students' understanding – they seem to enjoy it also". Other, more specific topics that were highlighted were increased use of formative and peer assessment and increased use of technology within the classroom (e.g. audience response systems), outside of the classroom (the learning management system) and to support assessment. More generally, and consistent with much of the existing literature on Learning Communities, participants reflected on the benefits of being able to discuss, explore and share problems and ideas and how the support and encouragement from colleagues enables them to deal with the challenge associated with developing their teaching practices.

5 CONCLUSION AND ACKNOWLEDGMENTS

The focus of this article has been to evaluate the impact of a single engineering Learning Community. Recognising the limitations of relying exclusively on self-

reports of impact, here we focused on evaluating the impact that this Learning Community had on programme development within our Department. A review of formal module descriptor documents reveals that Learning Community participants significantly contributed to the changes documented in our recently revised programmes. Specifically, while participants only represent 39% of the teaching staff within the Department, they contributed over 70% of the changes to module learning outcomes that focused on important graduate attributes. Given that the only obvious difference between participants and other staff within the Department is participation in the Learning Community, we tentatively conclude that this effect can be attributed to the Learning Community. Reflections from participants help support this conclusion.

This article helps to support the argument that Learning Communities can be a really effective mechanism for professional development within higher education. A direct implication then is that more higher education institutions should consider fostering and supporting Learning Communities to a greater extent than they currently do. A limitation of this research is its small-scale and particular focus – which makes it difficult to generalise findings. However, the findings are broadly consistent with existing research on Learning Communities. A second limitation is that, to date, we don't have evidence of a direct impact on student learning. Future work intends redress this limitation by documenting and reporting the impact that the revised programmes have had on student learning.

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UNDERSTANDING ENGINEERING STUDENTS' MATHEMATICS PROFICIENCIES: A STEP TOWARDS SUPPORTING DIVERSITY

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***Conference Key Areas**: Mathematics in the engineering curriculum. Diversity and inclusiveness.*
***Keywords:** mathematical proficiency, calculus, assessment, engineering students, diversity*

ABSTRACT

The economic demand for engineering graduates in South Africa coupled with low throughput in engineering degree programs have highlighted mathematics proficiency as a challenge. As engineering classes become more diverse, uneven mathematics preparation compounds the challenges facing engineering educators. During an engineering module, lecturers and students may come to realise that there is a mismatch between the expected and current mathematical proficiencies needed to engage with the disciplinary content. However, developing the required mathematical proficiencies within disciplines in addition to a full workload may overload students, and lead to failure. Starting with an understanding of the mathematical background of a cohort of students and sharing mathematical proficiency data with engineering lecturers soon after registration can help with planning interventions to develop specific skills needed for students to succeed in particular courses.

This quantitative research profiles the mathematical proficiencies of engineering students at a South African university and poses the questions: Based on pre-university assessments and final grades for a series of three semester-courses in calculus, what mathematical proficiency profiles can be identified? Are the profiles different for other demographic factors? We present an analysis of engineering students at a South African university that includes variables such as gender and grades for three university calculus courses, final school mathematics examinations, and National Benchmark Tests and their mathematics subdomain analysis. We suggest directions for further qualitative research to support the design of suitable interventions for diverse engineering classes.

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1 INTRODUCTION

In South Africa there is a national desire to increase participation in engineering [1]. Most South African higher education engineering programmes accept only students with the best school leaving grades, which is usually an indication that they will be capable of success at university. Despite the competitive selection of engineering students into higher education, student retention and failure to graduate is a concern and student success is not guaranteed.

As the number and diversity of students in higher education increases it becomes more important to have an understanding of who our students are and what their academic journeys have entailed thus far. Despite aims to redress effects of South Africa's historical unjust policies, South Africa's education system remains unequal resulting in uneven education. We argue that a tailored educational provision that best suits the students currently in our mathematics classes will provide a strong foundation and a good chance for success. We acknowledge that there are various factors that influence success in higher education such as an alignment between students' expectations and their experiences, acclimatization to the new environment, a good work ethic, persistence and hard work, good time management, and a passion for the chosen field of study [2]. This research looks at the academic profile of a cohort of engineering students at a South African university. Knowledge of students' academic profiles help inform interventions that lead to addressing the diversity in our classes. Interventions based on students' academic proficiencies are imperative to provide the support students need to further their studies successfully [3].

The study of mathematics has an important bearing on the success of engineering students. Many research studies raise concerns about the transition from high school to university and students' preparedness to study higher education mathematics. Even for those students who meet the mathematics requirements for engineering enrolment, mathematics problems still persist and the lack of mathematical preparedness and mathematical proficiency remain a barrier to the study of engineering [4] and subsequently a barrier to retention of engineering students.

The higher education landscape has changed considerably over the last 20 years and change has brought large numbers of students and with it diversity in mathematical proficiency, making the teaching and learning of mathematics a difficult terrain to navigate for both students and lecturers alike. We agree that "students must undertake a personal journey from their level of knowledge and skills at the point of entry to the level required to succeed in their chosen courses. All students have their own learning needs that must be met if they are to complete this journey successfully" [5]. This research paper reflects on the changing profile of our students with a view to questioning how our curricula and teaching and learning should change to meet and address this diversity to ensure success for all.

2 BACKGROUND

This research is situated in the Academic Support Programme for Engineering (ASPECT) at the University of Cape Town. ASPECT is a structured extended degree programme that allows students to complete a four-year engineering degree in five years, by spreading the load for the first two years over three years. Approximately 130 students join the Calculus 1 course and most follow on to Calculus 2. Both courses are taught by one lecturer (author 3) with assistance from tutors. Author 2 teaches repeat versions of Calculus 1 and Calculus 2. Author 3 teaches Calculus 3 each semester, with similar tutor support. Calculus 3 has an average of 98 students per semester, comprising students who pass the Calculus 1 and 2 sequence, students who pass the repeat courses of Calculus 1 and 2, and students repeating Calculus 3. The language of instruction is English.

The pedagogy subscribed to is one of students learning by actively engaging with the concepts. Lectures are interactive and tutorials center upon cooperative learning groups and are rooted in social constructivist theories of learning. A supportive learning environment is created through employing lecturers and tutors with expertise in teaching, scaffolding learning, showing patience and concern for students, encouraging study groups to form, and facilitating learning by appropriate use of technology.

2.1 Mathematics Competence in the Engineering Curriculum

A strong foundation in school mathematics is necessary to succeed at mathematics in tertiary studies. Negotiating learning in the various engineering disciplines requires a strong mathematical proficiency [6]. Mathematics forms the foundation of engineering studies, providing the engineer with logical thinking and problem solving skills. Taking into account the fundamental role that mathematics plays in engineering, [7] assert that more than providing basic knowledge for engineering, mathematics should foster critical thinking, develop problem solving and the capacity to analyse and accurately communicate information mathematically. In addition, [8] identify “different uses of mathematics in engineering practice: the direct usefulness of mathematical techniques and ideas to practice” and the “indirect usefulness - the ways in which mathematics contributes to the development of engineering expertise and judgment”.

2.2 Achievement In STEM Courses In Higher Education: Supporting Diversity

While science, technology, engineering and mathematics (STEM) undergraduate programmes have been widely acknowledged as challenging to students - evidenced by low student achievement - they are also characterised by a lack of diversity and by achievement gaps based on gender, socio-economic and racial groupings [9]. Programs that provide multifaceted, comprehensive support have been shown to reduce performance disparities [10]. In the South African context, extended degree programmes are designed to increase access and success in STEM programmes by previously (and currently) disadvantaged groups.

Pedagogical interventions such as active learning benefit all students and are especially beneficial for underrepresented groups [11]. Students in courses designed for active learning not only reduced the achievement gap, but reported an increased sense of community and self-efficacy [12]. Active learning is one way that the ASPECT courses support student success [13]. Arguably, another way of supporting the success of a diverse student cohort is by analysing the student academic profile. Curricula, teaching and learning interventions informed by these profiles can be designed to increase epistemological access and success in STEM programmes for all students.

3 METHODOLOGY

3.1 Context

The research participants were a cohort of 181 engineering students on an extended degree program who completed the last of three compulsory 12-week semesters of Calculus (Calculus 1, Calculus 2 and Calculus 3) in 2019. A minimum grade of 50% allows enrolment in the subsequent calculus course, with failed courses repeated in the following semester. Multiple repetitions of the same course are allowed.

3.1.1 Participants Demographic Profile: Race, gender and home language

The research cohort was 86% South African. The three largest of the 19 home language groups represented were English (48%), IsiXhosa (11%) and IsiZulu (11%). There were 114 male students and 67 female students. The race differentiation was 90 Black, 29 Coloured, 23 White, 17 Indian, 2 Chinese and 20 unknown due to students choosing not to convey their race.

3.2 Research Design

A quantitative analysis was used to explore the mathematical proficiencies of engineering students at a residential South African university, focussing on the academic preparedness of students and to identify groups of students to target for follow up qualitative research. The school leaving National Senior Certificate (NSC) mathematics examination grades and diagnostic information from the National Benchmark Tests (NBT) were used to explore students' entry level mathematical proficiency. Engineering students' mathematics performance in the three Calculus courses were analysed.

3.2.1 The assessments used: NSC, NBT and Calculus assessments

The National Senior Certificate (NSC) and National Benchmark Tests (NBT) complement each other and are both offered in English and Afrikaans, two of the 11 official languages in South Africa. The NSC mathematics examination, commonly referred to as "matric," signifies the culmination of twelve years of formal schooling and is a summative assessment which identifies to what extent a Grade 12 student has met the Curriculum Statement expectations as expressed in the Subject Assessment Guidelines.

The main objective of the NBT tests was to assess the entry level academic skills of candidates in Academic Literacy (AL), Quantitative Literacy (QL) and Mathematics (MAT). The NBT MAT test determines to what extent a school-leaver, who is applying to university, is prepared for the core mathematics demands of higher education study. The results of the tests are divided into four proficiency levels : basic (0% – 33%), lower intermediate (34% – 48%), upper intermediate (49% – 61%) and proficient (62% – 100%). The multiple choice NBT MAT test, aims to assess candidates' ability with respect to a number of mathematical topics which include problem solving and modelling, requiring the use of algebraic processes, as well as understanding and using functions represented in different ways, basic trigonometry, including graphs of trigonometric functions, problems requiring solution of trigonometric equations and application of trigonometric concepts, spatial perception (angles, symmetries, measurements, etc.), including representation and interpretation of two and three dimensional objects; analytic geometry and Euclidean geometry, data handling and probability and competent use of logical skills. Assessments for the Calculus 1 and Calculus 2 are both formative (weekly tutorial tests and 2-3 class tests in each course) and summative (3 hour written examination comprising 10-13 questions) focussing on problem solving and mathematical process skills.

3.3 Research Questions

We investigate the following questions :

1. Based on pre-university assessments and final grades for three semester-courses in calculus, what mathematical proficiency profiles can be identified?
2. Are the profiles different for other demographic factors?

4 RESULTS AND DISCUSSION

In this section we present the analysis of NSC, NBT and Calculus 1, 2 and 3 data.

4.1 National Senior Certificate (NSC) Data

From the 181 Calculus 3 students, mathematics grade scores for the school-exit National Senior Certificate (NSC) were obtained for 158 students. The remaining students had only letter grades such as A, B (n = 11) or did not have a mark available (n = 12).

High school mathematics grades had similar distributions for all students regardless of whether they passed or failed Calculus 3. The average NSC grades were 81.2% for passing students (females 80.1%, males 81.8%) and 80.5% for failing students (females 79.3%, males 81.0%). Figure 1 shows that Calculus 1 grades of non repeating Calculus 1 students are typically lower than high school NSC mathematics grades. Furthermore, higher grades for NSC Mathematics do not predict higher grades in Calculus 1.

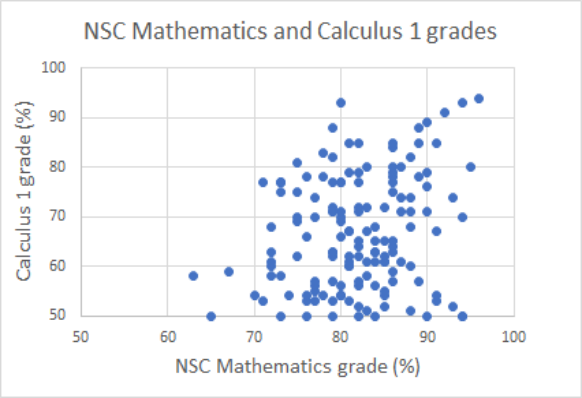

Figure 1: National Senior Certificate Mathematics and first-attempt Calculus 1 grades

It is not surprising that the NSC mathematics results is not a good discriminator for success in Calculus since students are selected and enter the program with high NSC mathematics results. This raises a need for additional information to complement the NSC mathematics results which can provide more discriminatory information to direct our teaching and learning interventions.

4.2 National Test (NBT) Data

The NBT MAT test is intended to provide a complementary picture of a school-leavers readiness for higher education mathematics demands. Of the 181 students who completed Calculus 3 in 2019, 161 had written the National Benchmark Tests (NBT) before applying for university admission. The NBT Mathematics data reveals that 56 students (16 female, 40 male) were considered proficient and 105 students (47 female, 58 male) were in the intermediate category. Proficient students are most likely to be successful in higher education mathematics courses whilst those in the intermediate category will require appropriate support in the form of augmented or extended programmes or skills provision if they are likely to succeed.
School leaving NSC MAT grades and the mean grades for three semesters of calculus based on the NBT MAT categories are shown in Table 1. The Calculus 1, 2 and 3 grades for all groups were very similar, with female proficient students achieving the highest average grades in Calculus 3. For students who repeated courses, grades for the final attempt were used in analysis, which is one reason the Calculus 3 grades are much lower than the Calculus 1 and 2 grades - failing students are yet to repeat Calculus 3. Missing values were due to exemptions or in the case of Calculus 3 grades, non-completion of the course.

Table 1: Average grades for National Benchmark Test Mathematics, National Senior Certificate Mathematics and three consecutive Calculus courses

	NBT MAT (%)	NSC Mat (%)	Calculus 1(%)	Calculus 2(%)	Calculus 3(%)
Proficient Females	77.4 *n = 16* *sd = 7.1*	84.2 *n = 16* *sd = 5.0*	66.5 *n = 16* sd = 12.7	66.6 *n = 16* *sd = 10.0*	57.3 *n = 14* *sd = 13.6*
Proficient Males	77.2 *n = 40* *sd = 7.1*	84.2 *n = 39* *sd = 6.4*	67.2 *n = 39* *sd = 12.0*	64.1 *n = 40* *sd = 11.8*	51.6 *n = 37* *sd = 14.9*
Intermediate Females	54.8 *n = 47* *sd = 8.1*	78.0 *n = 47* *sd = 8.5*	66.1 *n = 47* *sd = 11.0*	65.4 *n = 47* *sd = 12.4*	52.5 *n = 44* *sd = 17.7*
Intermediate Males	57.9 *n = 58* *sd = 8.1*	80.6 *n = 58* *sd = 6.0*	66.8 *n = 56* *sd = 10.9*	65.4 *n = 55* *sd = 11.1*	52.2 *n = 56* *sd = 16.6*

The lower performance of proficient male students in Calculus 2 and Calculus 3 despite achieving the highest average grade in Calculus 1 may suggest that factors other than school mathematics preparation impact their success in mathematics beyond the first semester, which further research can explore.
Figure 2 shows the race and gender profile of students with intermediate and proficient NBT MAT grades.

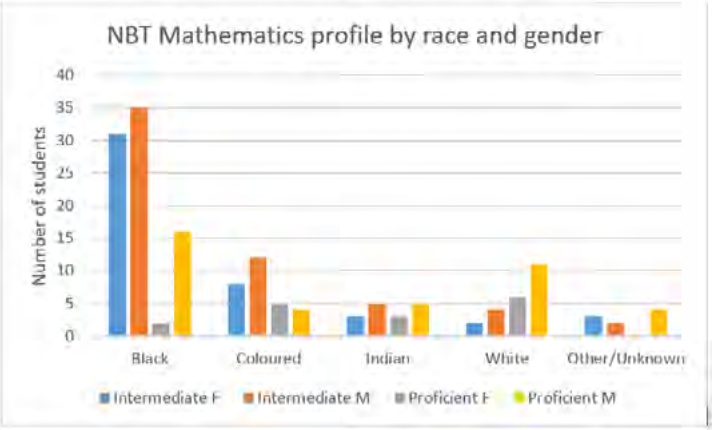

Figure 2: NBT Mathematics profiles separated by race and gender

Figure 3 shows the final grades for Calculus 3 separated by race and gender. There is evidence that the support provided in Calculus 1,2 and 3 evens out the differences in the pre-university assessments and is helping to narrow the achievement gap between race and gender groups.

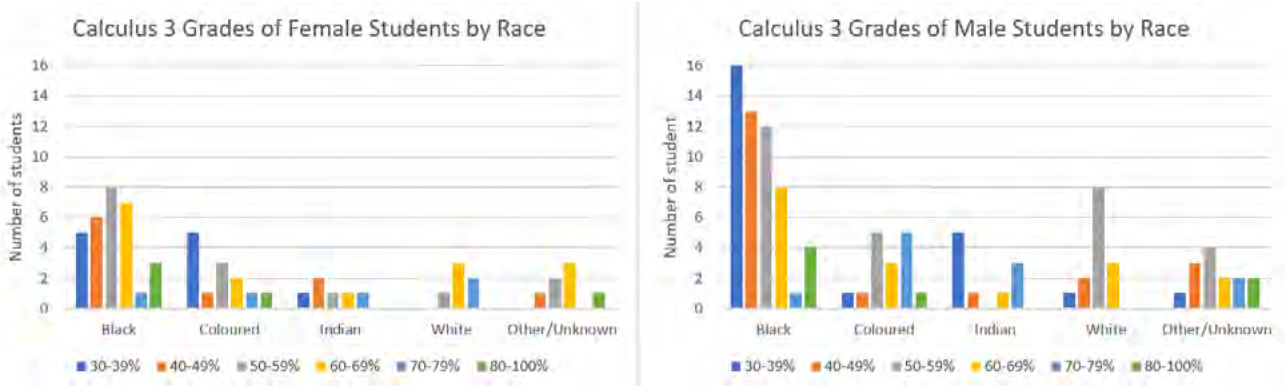

Figure 3: Calculus 3 grades separated by race and gender

Eighty-four students tested in the Academic Literacy (AL) proficient category whilst 77 students were intermediate, suggesting that the latter would have required curriculum integrated AL support to sufficiently cope with academic study at university. Most students with home languages other than English were Black (89%) compared to only 7% of Coloured, and 4% of White students. Accordingly, fewer Black students were proficient in NBT AL (26%), whilst 69% of the coloured students, 81% of the Indian students and 96% White students were proficient in NBT AL. Of the remaining 74% of black students who tested intermediate in AL only 6% reported English as their home language. This is not suprising as making meaning from English text is more challenging if English is not your first language.

Thirty six students were positioned as proficient in NBT MAT and NBT AL, of these 83% were English speaking. Of the 30 students who were proficient in all three domains of the NBT 83% were English speaking. How this translates into our university courses would have to be carefully monitored in order to provide necessary language support.

The QL test results indicate 70 students as proficient and 91 as intermediate, a concerning result considering the course content in this faculty is heavily dependent on mathematical and quantitative knowledge and skills, and for the most part the coursework in engineering involves calculations and an understanding and manipulation of numbers. Of the 56 students proficient in NBT MAT only 37 (66%) were proficient in QL.

Figure 3 shows the cohort performance on the NBT MAT subdomains (in order from left to right): Algebraic processing (AP), number sense (NS), functions and graphs (F&G), trigonometric functions and graphs (T), and geometric reasoning (GR).

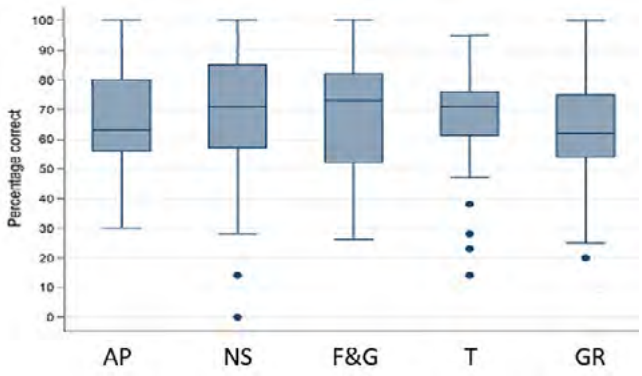

Figure 3: 2019 Calculus 3 cohort performance on NBT MAT subdomains

It is important to note that 50% of the cohort scored less than proficient for the key areas of algebraic processing and geometric reasoning that are foundational to engineering mathematics. Developing mastery of these topics, which are traditionally problematic for first year students in South Africa, is emphasised throughout the teaching in Calculus 1. The performance of the male students (n = 98) was slightly higher for all subdomains than for the female students (n = 63). In addition, the male students had higher medians, maximum scores and minimum scores in all sub-domains.

NBT MAT scores were not very discriminating but subdomain data provided important diagnostic information indicating mathematical concepts students find problematic. AL and QL results raise further issues important in engineering mathematics performance.

4.3 Calculus 1 and Calculus 2 Data

The average Calculus 1 grade for English home language, NBT MAT proficient males was 68.6% (n = 23), compared to 65.4% (n = 17) for NBT MAT proficient males whose home language was different from the language of instruction. For female NBT MAT proficient students, average Calculus 1 grades were 70.1% (n = 4) and 55.6% (n = 12) for students with and without English as home language, respectively. While the numbers are low, the data supports that studying in a language different from home language affects performance.

Figure 4 shows the Calculus 1 and Calculus 2 grade distributions for students who passed Calculus 3 first time (n = 115), and students who failed Calculus 3 (n = 31) in 2019. Results for students who passed after more than one attempt (n = 23) and students who did not complete Calculus 3 (n = 12) were omitted from analysis. Students who failed Calculus 3 had a wider range of marks for Calculus 1 compared to Calculus 2. The only mark range with more students who failed rather than passed Calculus 3 was 50-59% for Calculus 2, suggesting that the majority of students who pass Calculus 2 with a mark below 60% will need additional preparation or additional time to pass Calculus 3. All students with Calculus 2 marks of 80% or above passed Calculus 3.

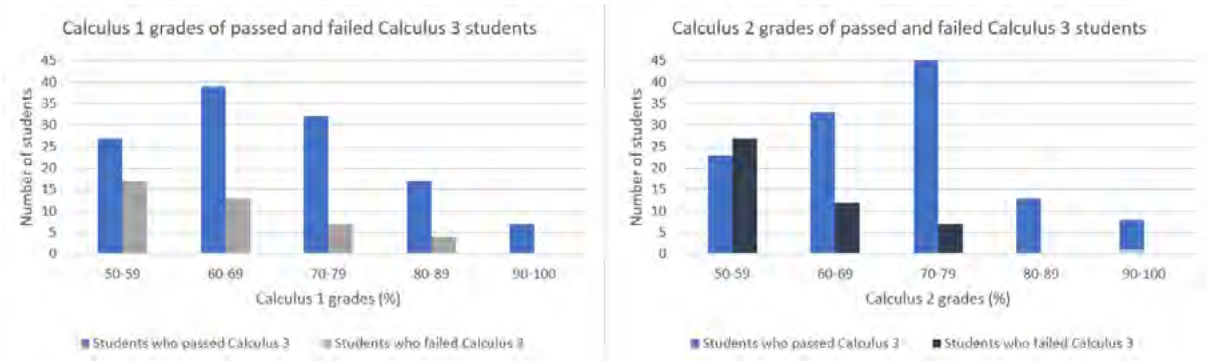

Figure 4: Calculus 1 and Calculus 2 grades for students who passed or failed Calculus 3

Only students with 80% or more in Calculus 2 are certain of passing Calculus 3. One factor can be a lack of mastery of content. Other factors contributing to failure in subsequent courses could be explored in further research, such as adjusting to more challenging content taught at a faster pace, a greater academic load from other courses, personal issues. Students with below 60% for Calculus 1 or Calculus 2 may need a further intervention before taking their next calculus course.

5 SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Summary

The main aim of the research was to use student performance on school leaving assessments and first year calculus assessments to highlight the need for and to suggest ways of supporting students. Good pedagogy requires us to know the academic profile of our students, including their strengths and weaknesses in mathematics so that we may respond appropriately with a curriculum in line with their mathematical proficiencies, whilst being mindful of students for whom current curricula or teaching strategies are least effective.

Based on pre-university assessments and final grades for three semester-courses in calculus, mathematical proficiency profiles were identified and some of the profiles were different for other demographic factors. While pre-university assessments profile students' mathematical proficiency to inform interventions for Calculus 1, the differences measured by these assessments before starting university do not seem to significantly correlate with results in first-year Calculus courses. The university experience may have a greater impact on student success, at least for students in the extended degree programme. It may be that the extended degree programme is developing students sufficiently, but further research is needed to investigate this.

The results of this research suggest that any invention directed to our first year Calculus students should involve academic literacy and quantitative literacy skills development. We suggest that the problematic school mathematics concepts be addressed for those students concerned in a blended learning intervention that is taken alongside their Calculus 1 course to help students bridge the gaps and therefore not allow these shortcoming to hamper their success in engineering mathematics.

A passing grade for Calculus 1, 2 and 3 is 50%. Students are able to pass a course by achieving high marks in one section and low marks in another, potentially creating gaps for courses that build on the neglected topics. Students in transition from Calculus 2 to Calculus 3, especially those with results of 50-59%, may be helped by interventions that address the issue of uneven engagement with course content by requiring mastery of all topics.

The next stage of this research will initiate inventions informed by these profiles to improve mathematical proficiencies especially at the interface from Calculus 2 to Calculus 3 where a steeper transition is observed. It is important to note that student support is not just a sum of services, interventions and learning opportunities provided but an "ethos" that is created. The ethos recognises that students have individual learning needs, that support should take the form of a variety of efforts both face to face and virtual, that learning development should not be stigmatised, that tutors and lecturers have an important role to play in supporting learning, that institutional support systems should be involved and engaged, and that students need to be motivated and inspired [5]. Any interventions initiated to address the transition to Calculus 3 should carefully consider this ethos if it is to succeed.

6 RECOMMENDATIONS FOR FUTURE RESEARCH

We acknowledge that, in addition to mathematics performance data, future research should include other factors which indicate students potential to succeed. Reasons for the lower achievement of proficient male students beyond their first calculus course could direct the development of support, such as the adjusting course load, providing support in courses other than mathematics, or behavioural or socio-psychological support. Based on the NBT AL analyses above, further research should explore how academic literacy can be supported for engineering students with home languages different from the language of instruction.

Future research could also profile the diversity of students as defined by an inter-relation of the various factors - academic, demographic and other - which have a bearing on student success. Further exploration is needed on how these profiles can be leveraged to support student success through the design of suitable interventions. Such research would be valuable in the light of student retention and success in STEM courses.

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COMMUNITY-BASED SERVICE-LEARNING FOR FIRST SEMESTER ENGINEERING STUDENTS

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Keywords: *Community-based service-learning, service-learning, service-based learning, engineering education, communication skills for engineers*

ABSTRACT

Community-based service-learning refers to the practice of combining learning outcomes in formal education with community service. The goal thereby is to make the educational outcomes and their achieving valuable not just for the learner, but also for his community. Unfortunately, service-learning remains underrepresented in engineering education today, while its potential in this domain is exceptionally high. In this paper, the context and outcomes of a community-based service-learning project for first semester engineering students are described. The project was implemented within a *Communication skills for engineers* course where students could complete a part of the course requirements by preparing a simple project using *mBot* educational robots and *micro:bit* boards, organizing the presentation of the project in an elementary school, and delivering a workshop for the pupils. Students' motivation, learning outcomes, and satisfaction with the project were investigated in order to help developing similar projects and increase students' voluntary participation. Research findings suggest that the project outcomes are beneficial for its stakeholders, and that the key motivators for students to take part in it are the importance of project results for others and practical work with technology.

1 INTRODUCTION

1.1 Community-based service-learning

Community-based service-learning, sometimes also called *community-based learning* or *service-learning*, refers to the practice of combining meaningful community service with academic learning, personal growth, and civic responsibility [1]. This implies making the educational outcomes and their achieving in formal education valuable not just for the learner, but also for his community. Examples of service learning projects include the EPIC programme started at the Prude University [2], where students work on projects with local community organizations to help them those organizations in identifying and solving problems, or the Electrical & Electronic Engineering programmes within the College of Engineering and Informatics at the National University of Ireland [3], where service-learning even became an obligatory element of a four year study programme.

It is sometimes easy to confuse service learning with volunteering, internships, or project-based learning in general, yet volunteering does not imply a connection to improving learning outcomes, nor a connection to a course in formal education, while internships and project-based learning do not imply that the achieved results will have a positive impact on the community. Still, internships, project-based learning, and service-learning are all active learning approaches anchored in real contexts, which is associated with great improvements in achieving learning outcomes [4–6]. This does not come as a surprise, since problem solving, critical thinking, and reflection are inherent to those approaches [7].

Research has confirmed that service learning has a variety of positive effects on students including development of a sense of responsibility towards their community [8, 9], improvement of students' course-related learning outcomes [10], students' personal growth [11, 12], and improvements in students' problem solving skills [13].

In this paper, a project of including service-learning into a first-semester communication skills for engineers course is described. While very few such examples have been reported in the literature, such courses hold a great potential for service-learning due to their learning outcomes – the ability to efficiently communicate technical ideas and knowledge others.

1.2 *Communication skills for engineers* course

Communication skills for engineers or short *Communication skills* is an undergraduate level, first-semester, obligatory course at the University of Zagreb Faculty of Electrical Engineering and Computing. The course is worth 4 *European Credit Transfer System* points and every year approximately 670 students are enrolled in this course. The learning outcomes of the course include understanding and mastery of key media for communication of engineering professionals including e-mail, slideshows, resumes, writing, pitching, presentations, photography, and video. The course also includes topics like meetings, personalities and conflict resolving. Since the course is focused on learning outcomes that are very practical in their nature, there is an inherent problem with their acquisition and assessment in a

scalable way. Solving a multiple-choice quiz has only a limited value when the desired learning outcome is to prepare or at least introduce a student to holding a 60-second presentation or writing a formal email. Using authentic activities and their assessment, on the other hand, is impractical or impossible for large enrolment courses.

To help solving this issue while, at the same time, impacting and helping the community, a community-based service-learning project was introduced with help of the Institute for Youth Development and Innovativity (IYDI), a Croatia-based non-profit organization, on a project of STEM (Science, Technology, Engineering, Mathematics) popularization [14]. Students' role in this partnership was to develop simple technical projects using *micro:bit* boards and *mBot* robots with help of their IYDI mentors, and to present those projects in workshops in elementary schools to encourage pupils' interest and familiarize them with the potential and practical aspects of some STEM-related topics.

2 METHODOLOGY

2.1 Project description

For their individual projects, students could choose between *mBot* educational robots and *micro:bit* boards, or combine both. Students participated in a one-day workshop about those two technologies organized by IYDI after what they had two weeks to develop the topic for their project and have it approved by their IYDI mentors. By the end of the semester, students had to develop their individual projects, prepare digital learning materials based on which anyone interested could reproduce them (the developed materials would later be published on the IYDI website), find an elementary school in which they would present it to pupils in a workshop, and deliver the workshop typically in a 90-minute session. Based on the grades from their IYDI mentors, teachers, and pupils who participated in their workshop, students would be awarded credit for their final course project, as well as course credit for the presentation activity. The total value of those two course activities is 34% of overall course credit.

For IYDI, those students were a help in achieving their mission of popularizing the STEM filed to elementary school pupils and increasing IYDI's outreach to elementary schools. Due to the decrease of general interest for STEM-related fields [2], this goal is considered particularly important. In context of the *Communication skills*' course, this project allowed students to practice their communication skills in the most authentic settings, by finding a school where they would present their work, doing all communication prior to their arrival, preparing the workshop, and, finally, delivering the workshop in front of an audience.

2.2 Data collection

After the project was finished in January 2020, data from students was collected in order to get feedback about students' experiences with this project, their motivation to participate in it, the learning outcomes, and their suggestions for improvements. Data was collected using an online questionnaire. A total of 19 students participated

in this project and 17 of them completed the online questionnaire. The questionnaire included students' identification number, yet it was available after their course grades has been finalized to encourage them to submit their honest opinions and not fear their answers would affect their course grade.

3 RESULTS

3.1 Survey results

3.1.1 Time cost of the project

It was assumed that the service-learning would be more time-consuming then the usual course activities of final project and pitch. Even though this could discourage students from participating, it was emphasized in the service-learning project presentation on the introductory course lecture. Survey results revealed that 7 of 17 students (41.18%) assumed, prior to starting it, that service-learning project would take them more time than the usual course project, the same number said that they weren't able to assess the time required for the project at that time, while 3 of them still assumed this would take them less time than alternative activities.
Students who, instead of the service-learning project, participated in the regular course activities reported at the end of the semester that they on average invested slightly less than 15 hours of work into their final projects, and slightly less than 5 hours of work into their pitches. On average, students who participated in the service-learning project reported a slightly higher workload compared to students who did not participate: 15 hours to develop their projects technically, 2 hours for communication with schools, 5.5 hours to prepare for a workshop, and 3 hours to travel to a school and deliver the presentation. On average, their workload was around 25.5 hours, which is 27.5% more than students not participating.
These results suggest students mostly did not assume the service-learning project would save them time compared to the usual course activities, and this still did not discourage them from applying. This is important since it was intended to include students who are motivated intrinsically in the project, and not those who find it opportunistic. The workload students reported in the project was still lower than it was expected, yet this is not important if the project goals are achieved.

3.1.2 Key motivating factors

The survey items regarding students' motivation first included a question if they had chosen to participate in the service-learning project because they liked it or because they disliked all other options available as the final Communication course's project. Only one student reported that this is the option he disliked least. Other 16 students were further asked what were the most important reasons that they wanted to participate the service-learning project. The answers to this were: because the project results are valuable for someone else (12/16, 75%), because it includes practical work with technology (10/16, 62.5%), because it includes teaching and delivering a workshop (9/16, 56.25%), because it includes working with other people (5/16, 31.25%), because it can be done in teams (5/16, 31.25%), and because it

seemed like less work to do (3/16, 18.75%). In line with those results, it seems that the two most important factors in this choice are that the project results are beneficial value for other society members, and that they include practical work with technology.

3.1.3 Learning outcomes (self-)evaluation

Students' learning outcomes were evaluated through their workshop quality, assessed by their audience, and the quality of the video and textual materials they developed for their project, assessed by their IYDI mentors. Workshop participants across all schools, both teachers and pupils, expressed their great satisfaction and submitted that as a textual statement to IYDI. The IYDI mentors additionally evaluated the quality of developed video and textual learning materials and students' engagement during the semester. Students were mostly very satisfied with their evaluations, and IYDI mentors with their works.

In the survey, students were, additionally asked to reflect on their learning during the project. On a scale from 1 (*very little*) to 4 (*a lot*) students on average reported that they learned about presenting their work to the public (3.24), delivering a group workshop (3.47), organizing an event and leading formal communication (3.41), developing digital learning materials (3.24). They assumed those were significantly higher than, for example, the advances in knowledge related to the technology they were using (2.82).

Overall, those results suggest students benefited from participating in this project. Some of the included activities and related learning are difficult to implement directly in the curriculum and are available only in context of this project, although they are directly related to the *Communication skills* course's outcomes.

3.1.4 Schools' feedback

Unfortunately, no feedback was acquired directly from schools where students held their workshops, and their feedback therefore remained anecdotal, based on what school staff would report back to IYDI mentors. The few recorded cases of schools reporting back were positive and suggested students managed to capture pupils' interest.

3.1.5 Proposed improvements

Some students suggested potential improvements and their comments were thematically related to improving coordination and support during the project, possibly by adding milestones or additional physical meetings (4/17), and to contact the school and learn about the prior knowledge of workshop participants at the beginning of the project, so that the topic can be better suited to them (2/17).

Students reported that they would definitely (15/17, 88.2%) or possibly (2/17, 11.8%) recommend participating in this project to their younger colleagues next year, which was seen as another sign of their satisfaction, even with the higher project workload.

Additionally, to assure workshops are suited to pupils' age and needs, mechanisms should be implemented to evaluate every workshop directly, in every school, after it

has been completed. Discouraging pupils' interest due to a badly prepared workshop would be the least desirable outcome, and to avoid it, good communication with schools and a direct feedback from their pupils would certainly be helpful. A survey to evaluate workshops aimed at pupils will be included in the next iteration of the project.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper reports on the first results of a community-based service-learning project in which computer and electrical engineering students within a Communication skills course helped a local non-profit organization to extend its outreach in popularizing and raising pupils' knowledge about some STEM-related topics. These results suggest this project is beneficial for all its stakeholders and that it helps students achieve course's learning outcomes. The importance of project results or other society members and practical work with technology are identified as key motivators for students to take part in it, while providing more guidance and technical help are identified as key potential improvements of the project. Follow-up implementation and research will focus on interventions to stimulate students' interest to participate in this project and formalize and better assess learning outcomes.

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ACADEMIC SUCCESS OF FIRST-YEAR-STUDENTS – WHAT'S THE DIFFERENCE BETWEEN MECHANICAL AND CIVIL ENGINEERING STUDENTS?

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Keywords: *university dropout, civil engineering, mechanical engineering, engineering mechanics, study success*

ABSTRACT

First-year students of mechanical and civil engineering show a high degree of heterogeneity. The purpose of the present study is to investigate the two engineering courses with regard to which characteristics at the beginning of the studies are more likely leading to academic success. Different selected variables are examined, in terms of demographic variables, special knowledge (mathematics and engineering mechanics) and academic success. It can be shown that demographic variables make a significant difference and have a corresponding impact on the person ability achieved in the applied knowledge tests by the students of both engineering courses at the beginning and end of the first semester.

1 INTRODUCTION

A catchphrase that is currently frequently used in the discourse about the reform of the German higher education system is heterogeneity. In general, heterogeneity is understood as a temporary, attributed inconsistency that exists between members or a part of members of a specific group based on one or more criteria [1]. The student body is becoming increasingly heterogeneous [2, 3]. This raises concerns that it can become more and more difficult to design large lectures / courses that do justice to (almost) everyone [1, 4]. It can be assumed that certain characteristics of the students correlate with their performance and therefore increasing diversity in those characteristics can also result in an increasing heterogeneity of their performance.

The University of Duisburg-Essen [UDE] (Germany – North Rhine-Westfalia) is characterized by a high degree of heterogeneity among its students. This university is in the Ruhr region, where the students often come from low-income and / or poorly educated social classes, and usually have an immigration background. On the one hand this large group of students has a high affinity for scientific and technical subjects, on the other hand the students of this group have particular problems during their studies. They represent a special risk group with regard to their academic success and even drop out of university down the road [5]. An empirical study at the UDE found out that gender, a non-academic family educational background, a history of immigration, a lack of a vocational qualification and a below-average higher education entrance [HEE] grade (Abitur) are among the factors that delay the completion of the study and also increase the risk of student drop-out [6, 7].

This paper examines the current state of the two most strongly represented engineering courses at the UDE [8] – mechanical engineering [ME] and civil engineering [CE] – based on empirical findings. Various socio-demographic characteristics and knowledge tests were selected for the present analysis. In the following, the background of these factors and - initially purely descriptive - their characteristics in both engineering courses are presented.

2 METHODOLOGY

Demographic variables like age, gender, HEE grade, type of HEE acquisition and the corresponding location, participation of mathematics and physics courses at the upper school level, delay before begin of the studies, immigration, family educational background and vocational education were recorded as part of a questionnaire. This demographic questionnaire was completed subject-independent by all studied first-year students at the beginning of the first semester [MP1].

The scales for recording the subject-related study prerequisites (previous knowledge) and the course performance (special knowledge) were also applied as paper and pencil tests at the beginning [MP1] and at the end of the first semester [MP2]. The test (multiple-choice-single-select format) contains mathematic and engineering mechanics [EM] items from the item pool by Dammann & Lang [9] – both subjects are considered to be of central importance for the two engineering courses [10]. These tests are used in order to have an objective measure that reflects the special knowledge as part of the students academic success in the respective courses. The tests are scaled using the 1-PL-IRT model (Rasch). The tests are showing satisfactory reliabilities and separations for MP1 (WLE reliability = .77, EAP reliability = .78), therefore the person ability (WLE) can be used for the subsequent analyzes.
In order to be able to compare the WLE and to calculate the subject-specific increase in knowledge, the item difficulties at MP2 (special knowledge) are fixed to the values of the IRT-scaling at MP1 (previous knowledge). The calculation of the model for MP2 with fixed item difficulties also shows satisfactory parameters (WLE reliability = .84, EAP reliability = .84).

3 RESULTS

3.1 Heterogeneity of both engineering courses

The presentation of the results initially shows basic demographic characteristics of the ME and CE students. These characteristics reflect their fundamental heterogeneity. Also the basic variables are characterized by the fact that they are constant over time e.g. age, gender, HEE (grade, type of acquisition, corresponding location and participation of mathematics and physics courses) and family educational background. The cognitive competence and the personality of the students are also counted as exogenous student capital.

By looking at the individual characteristics, first insights into the specifics of first-year students can be found. For this purpose, socio-demographic data is used, which can provide information about the heterogeneity of the considered groups.
The applied questionnaire was answered by 88 ME and 290 CE students. The descriptive analysis of the data shows an average age of 20.1 years for ME and 20.7 years for CE students; the two groups do not differ significantly in average age.
The gender distribution of ME students is 81.6 % men and 18.4 % women, in contrast the distribution among CE students is 67.1 % men and 37.9 % women. This means that the gender distribution of the two groups differs significantly from one another (n_{ME} = 87, n_{CE} = 289, χ^2 (1) = 6.74, p = .009, Cramers V = .134). The share of women in the field of CE is already relatively high for an engineering study course, generally the numbers vary between 12 and 19 % [11].

The surveyed ME students achieved an average HEE grade of 2.55, while the CE students achieved a significantly inferior average HEE grade of 2.81 (n_{ME} = 86, n_{CE} = 256, t (340) = -3.67, p = .000).
Significant differences can also be observed in the acquisition type of the HEE (n_{ME} = 89, n_{CE} = 288, χ^2 (4) = 15.58, p = .004, Cramers V = .203). While 64.0 % of the ME students have obtained their HEE at a secondary school (Gymnasium), 20.2 % obtained their HEE at a comprehensive school (Gesamtschule). Compared to the ME students, 56.6 % of the CE students obtained their HEE at a secondary school, while 29.2 % obtained it at a comprehensive school.
The remaining students of both groups obtained their HEE at a vocational college, by second-chance education or miscellaneous. Since the curricula in the individual school types differ in the course content, it cannot be assumed that the level of knowledge at the beginning of the course is homogeneous.
The HEE was acquired from 96.3 % of ME students in North Rhine-Westfalia; only three students acquired it in another federal state. No ME student has attained the HEE abroad. 87.5 % of the CE students acquired their HEE in North Rhine-Westfalia, six students in another federal state. 10.4 % of the CE students attained their HEE abroad, the majority of them in Syria (n_{ME} = 81, n_{CE} = 289, Fisher-Test: 16.27, p = .002).

There are no significant differences in the choice of basic or advanced mathematics courses at the upper school level. Almost a 50 % / 50 % (basic / advanced) distribution

can be determined for the CE students and a 35 % / 65 % distribution for the ME students. In contrast, significant differences can be identified in the choice of the physics courses. On the one hand, 35 % of the ME students chose the basic and 25 % the advanced physics courses at the upper school level. On the other hand, 32 % of the CE students chose the basic and 8 % the advanced course. In contrast it is striking that 40 % of the ME and almost 60% of CE students have never attended a physics course at the upper school level ($n_{ME} = 84$, $n_{CE} = 234$, $\chi^2 (2) = 18.55$, $p = .000$, Cramers V = .242).

In addition to the acquired knowledge and skills that enable students to study, the delay in secondary education also plays a role, as Henn and Polaczek [12] have already noted. The ME students who started their studies in the winter semester 2018/19 received their HEE 1.5 years before starting their studies. The CE students who obtained their HEE 1.9 years before starting their studies are showing no significantly larger time delay regarding the transisition from school to higher education.

The immigration background of the students was recorded in the form of the native language. When asked whether German is their mother tongue, 75.3 % of ME students agreed. In the cohort surveyed, therefore 24.7 % do not speak German as their first language. On a three-level scale with regard to their German language skills, 69.4 % of the non-native speakers evaluate their German language skills as “very good”, 27.8 % as “good”, while just 2.8 % choose the lowest level “basic knowledge”. Regarding the distribution of whether German is the mother tongue, there are significant differences relaiting to the CE students ($n_{ME} = 89$, $n_{CE} = 290$, $\chi^2 (1) = 15.02$, $p = .000$, Cramers V = .199). Just 52.1 % of the CE students speak German as their native language, corresponding 47.9 % are not speaking German as their mother tongue. Here, 66.2 % of the non-native speakers state that their German language skills are “very good”, 33.1 % as “good”, while here, too, the lowest level “basic knowledge” is chosen by 0.7 %.

The family educational background is characterized by a four-stage classification according to the concept by the DZHW [13]. The characteristics of the vocational education of the father and mother of the students are divided according to the following classification: low = one parent has a vocational (non-academic) degree, average = both parents have a vocational (non-academic) degree, enhanced = one parent has an academic degree, high = both parents have an academic degree. The division according to the family educational background shows no significant differences in the distribution of ME and CE students. As shown in Fig. 1 a comparison with the results of the 21st social survey (universities from 2016) of the DZHW [13] shows that a larger share of the cohort of CE students have a low or average family educational background (almost 60%) compared to the 21st social survey (42%) [13]. Accordingly, the share of enhanced or high family educational background is lower. In contrast, the ME students almost exactly achieve the mentioned values of the DZHW study [13].

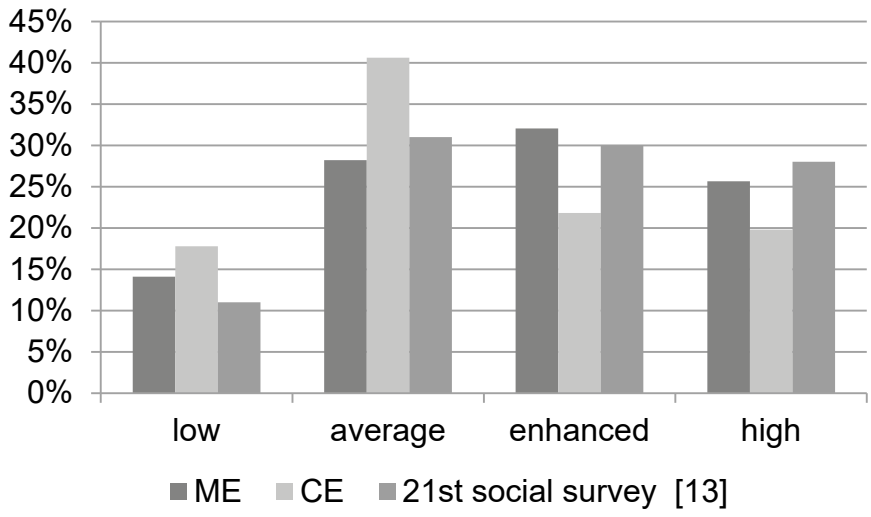

Fig. 1: Bar chart of the family educational background distribution

8% of the total cohort of ME students have completed an vocational education before starting their studies, of which 33 % have similar content in their vocational education related to their ME studies. 10.3 % of the CE students have already completed an vocational education before starting their studies, with 75.9 % a significantly higher share has similar content in their vocational education related to their CE studies ($n_{ME} = 2$, $n_{CE} = 22$, χ^2 (1) = 4.17 , p = .041, Cramers V = .345). 13.7 % of ME students already have study experience, there is no significant difference regarding CE students with also 13.7 %.

After the heterogeneity of the students has been highlighted in this chapter, it should be examined whether the students also differ in terms of their average person ability in the knowledge test, and whether there are correlations between the average personal ability and the mentioned demographic variables.

3.2 Relation between person ability and demographic variables

Students from both study courses start with similar average person abilitys regarding their previous knowledge (MP1). For the special knowledge (MP2) it can be seen that the students of CE performed significantly better in these tests ($n_{ME} = 56$, $n_{CE} = 58$, t (112) = -.279, p = .000) (Fig. 2).
The average person ability regarding previous knowledge (MP1) and special knowledge (MP2) were compared with one another in order to check the students increase in knowledge and thus their academic success (Fig. 2). At MP2, a large number of the students no longer participated in the study, so the number of participants dropped noticeable. To test the extent to which these average values differ from one another, t-tests were calculated. There is a significant difference in the increase in special knowledge for ME ($n_{ME} = 52$, t (51) = -6.16, p = .000) and CE students ($n_{CE} = 46$, t (45) = -9.68, p = .000).

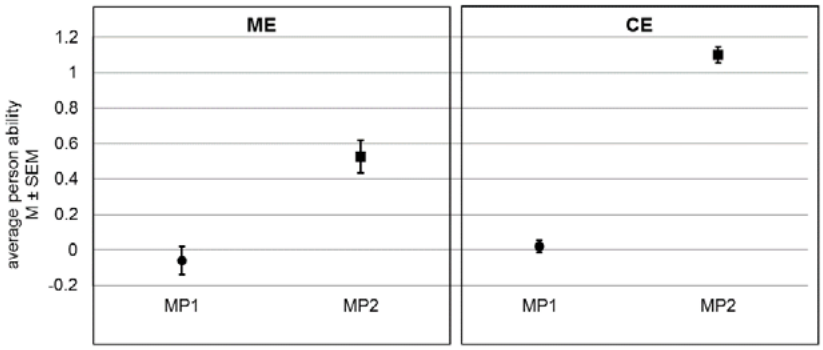

Fig. 2: Error bars of the average person ability for the ME and CE students at MP1 and MP2

In the following, correlation analyzes are used to examine the correlations that emerge for ME and CE students between the average person ability achieved in the knowledge tests at both measuring points and some of the recorded demographic variables. Table 1 shows the correlation of the average personal ability and the HEE grade. All correlations are negative medium strong and highly significant.

Table 1. Correlation between average person ability for the ME and CE students and the HEE grade

		HEE grade	
		ME	CE
average person ability	MP1	-.308**	-.356**
	MP2	-.383**	-.385**

** < .001

For a closer examination the HEE grades were grouped – according to the grading in Germany – (A = 1.0 - 1.4, B = 1.5 - 2. 4, C = 2.5 - 3.4, D = 3.5 - 4.0) and considered in relation to the average person ability in previous and special knowledge (Fig. 3). Generally strong characteristic error bars indicate a low n within the group.
It is clear that the person ability of all students improves in both engineering courses, regardless of the HEE grade. However, you can see that students with a worse HEE grade are not in the position to close the gap to the studends with better HEE grades. Anyhow, the CE students always achieve a better person ability than the ME students. It must be emphasized that for the CE students (grouped grade D) at MP2 the trend is not the same as for the other grouped grades, this could be justified by the fact that the this group consists of only 2 students.

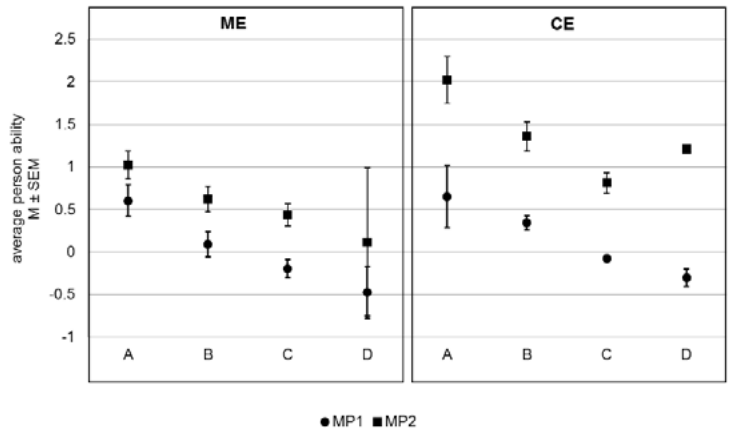

Fig. 3: Error bars of the average person ability for the ME and CE students at MP1 and MP2 divided by the HEE grade

When choosing a course at the upper school level, the subject mathematics was divided into students who have attended a basic course or an advanced course (Fig. 4). The correlation coefficients between average person ability and the choice of course in mathematics are shown in Table 2. For ME and CE students at MP1 and MP2, there is a correlation between average person ability and the choice of the mathematics course. This correlation is also evident for both student groups at MP2. The same division into basic course and advanced course was also made for the school subject physics, but here is also the possibility of not chosing the subject at all. For the ME students, a correlation can be shown for the average person ability of MP1 and MP2. A correlation regarding the CE students is just existent for the average person ability at MP1 (Table 2).

Table 2. Correlation between average person ability for the ME and CE students and the subjects mathematics and physics

		mathematics		physics	
		ME	CE	ME	CE
average person ability	MP1	.326**	.304**	.447**	.260**
	MP2	.294*	.345*	.411**	

** < .001, * < .005

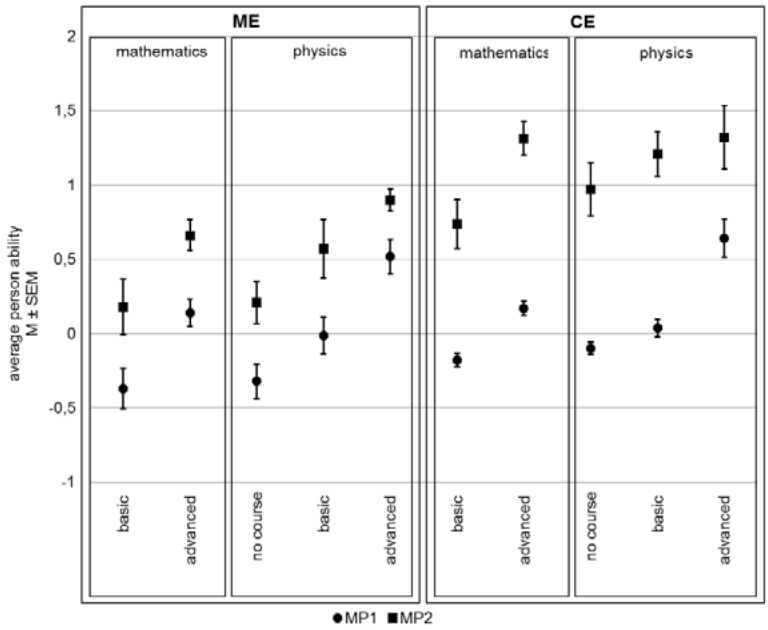

Fig. 4: Error bars of the average person ability for the ME and CE students at MP1 and MP2 divided by the course type of mathematics and physics at upper school level

The immigration history also has a significant impact on the person ability of individual students. For ME students, there is a correlation between the average person ability and their native language with a negative effect ($r = -.240$, $p < 0.028$) at MP1 (Table 3). For CE students only a correlation exists between the average person ability at MP1 and the native language.

Table 3. Correlation between average person ability for the ME and CE students and the native language

		native language	
		ME	CE
average person ability	MP1	-.240*	-.308**
	MP2	-.273*	

** < .001, * < .005

The family educational background also provides information about the person ability (Fig. 4). With increasing family educational background, the average person ability at MP1 for both study courses increases. No significant correlation can be shown both engineering courses at MP2.

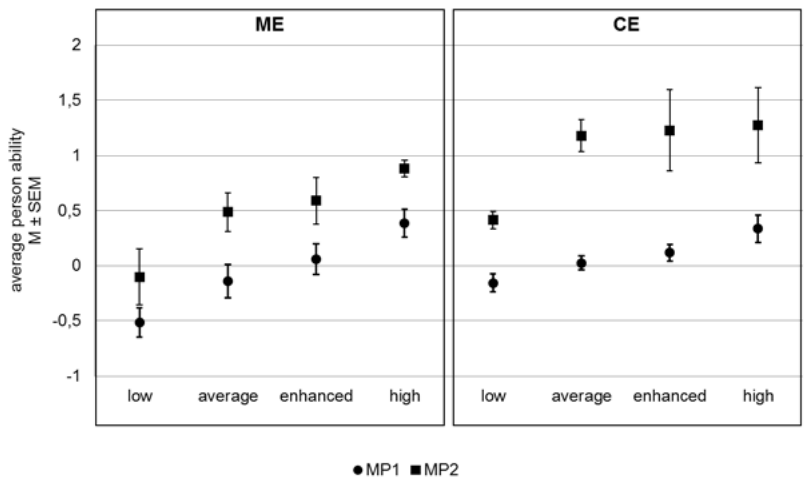

Fig. 5: Error bars of the average person ability for the ME and CE students at MP1 and MP2 divided by the family educational background

4 SUMMARY

The first-year students of ME and CE at the UDE are characterized by great heterogeneity, as the study carried out with regard to school education, immigration background and vocational education. The differences in vocational education affect only a very small part of the overall cohort. The school education, i.e. the acquisition of the HEE differs mainly in the achieved HEE grade and in the type of school in which the HEE was acquired. Accordingly, more than a third of the students acquired the HEE at a comprehensive school or through vocational education. The courses at the upper school level are also of interest. While for the ME students the choice between basic and advanced course was almost the same in mathematics, almost 40% did not participate in the courses of physics at all (60 % of the CE students), although it is important for engineering studies.

Both student groups showed significant correlations between the average person ability – both in terms of previous (MP1) and special knowledge (MP2) – and the HEE, the choice of courses in mathematics and physics, the native language and the vocational education.

Based on these findings, support measures for students in the preliminary and / or introductory phase of their studies should now be developed by means of a suitable diagnostic option.

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THE CIVIL'IN PROGRAMME

A PEER MENTORING PROGRAMME FOR FIRST-YEAR STUDENTS OF CIVIL ENGINEERING

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ABSTRACT

In 2015/2016, the CIVIL'in mentoring programme was created to better integrate new first-year students of the Master of Civil Engineering (MIEC) at the Faculty of Engineering of the University of Porto (FEUP).
Since then, the programme has a peer mentor assigned to each new student to accompany him from the beginning until the end of the first academic year. Every mentor is always associated with a professor for support and orientation. Mentors receive actions of specific formation in the beginning of the year. As expected, according to results obtained from a survey, mentors expressed the benefits achieved from this programme, namely positive attitude, teamwork, leadership and communication skills that will be relevant for their future integration in the professional environment.
Evaluation of CIVIL'in has been done by daily observation, analysis of surveys by both mentors and students and by academic marks results when compared to a

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control group. The overall results have been satisfactory and it is believed that adjustments in routines and some particular practices have contributed to steady improvements of the programme. This methodology still remains essential for CIVIL'in to fulfil the initial established purposes.

1 INTRODUCTION

At the beginning of the current decade, economic and social crisis in Portugal had a large impact in the industry and particularly in civil construction. This was reflected in the demand for engineering courses, either in quantity or in quality, with drastic results in what concerns Civil Engineering. The number of candidates to this course dropped and also did their average marks as a consequence. Thankfully, students with strong motivation and high marks kept applying to this course.

National wide, the number of Civil Engineering candidates decreased in successive years, without any vacancies filled in several schools. In Portugal, only the universities of Lisbon and Porto always managed to fill the places available, however with a different average profile of the students when compared to pre-crisis situation: lower marks of access, less top private schools as background and a majority of students having Civil Engineering as a second, a third and even a further option.

In the early years of the 2010 decade, the FEUP Department of Civil Engineering started dealing with a different "average student" of those nearly two hundred admitted to the first year: with lower scientific preparation and economic resilience and, above all, less motivated. This was confirmed by the difficulties of students dealing with the courses subjects, and some of the best students changing in the second year to other study cycles.

For the benefit of the future of Civil Engineering in Portugal and, most of all, for the success and well-being of those students, special actions must arise. However, some specific features of Portuguese education should not be neglected.

As a rule, admission to higher education is regarded as a very important step in student's life and traditionally represents the achievement of one of the greatest dreams of the youngsters. On the other side, and particularly in FEUP, this phase is accompanied by intense personal and social challenges which, in general, students are not entirely prepared. Adaptation to a new daily routines, a new social environment, and even a new city and residence, may require a positive contribution from that new community. The question is always how to build a collective programme to provide that kind of help.

Simultaneously, in Portugal, the idea that the only "mission today of the University is to feed and sustain the knowledge society" remains very entrenched [1]. This drawback must be urgently changed since, in addition to training professionals with extensive scientific and technological background, higher education must also be concerned with the education of citizens as a whole. In this way, the University must have a leading role in training students to the new world and thus provide the necessary conditions to make this transition in a more balanced way and without major difficulties.

2 PEER MENTORING AND OTHER TEACHING / LEARNING THEORIES AND MODELS

Having all this in mind, it was necessary go through education publications to be aware of the procedures that could respond to that imperative mission of adding something new to the established routines. Some innovative materials and new tools for teaching and latest educational technologies (such as e-learning and virtual labs) were already used with some success in different study cycles of FEUP. These experiences have the classroom as their natural habitat and it seemed too hard to implement them on a needed larger scale.

With a broader scope, new outside classroom technologies, such as gamification, MOOC, OER, are emerging and were also considered, but those kinds of breakthroughs would consume lots of time and resources and undermine a necessary quick prompt response.

Peer monitoring stood up as very reasonable option. Across the world [5, 6, 7] and already in a few Portuguese institutions [8], peer mentoring had proofed to be a positive way to support new students in their academic integration. All these experiences were reflected by [7], evaluating "peer mentoring as the most effective strategy to increase retention and satisfaction". In Católica-Lisbon School of Business & Economic a mentoring programme was adopted, gathering first year students with alumni, so that since the beginning of the academic course, students can be related with professional environment [10]. In Grifith University, each course provides different mentoring programmes fulfilling expections of their academic choice, increasing the sense of belonging in a supportive network [11].

Also to teachers is important to engage in the projects to spread knowledge and a holistic well-being and ongoing development [12].

It came up as a low-level resources consumer, mainly based on a competency, learning skills and dedication from the participants. Peer mentoring performed by students from advanced years seemed to be a good strategy for the young mentees to enhance integration in the school, expand social connections and improve academic results.

As a standard model, mentoring is supposed to be conducted by tutorial during the first academic year, being assigned to the new student a single mentor, who has the responsibility of helping him in his integration from the beginning of the study cycle until the end of the first academic year, on his didactic, logistic or personal challenges. Experience would validate this model, but also acknowledge adjustments to less expected situations.

3 GOALS AND TARGET EXPECTATIONS

The goal of the CIVIL'in programme was, from its beginning, to create a collaborative academic environment among first-year students, mentors and academics, favourable to the students' integration, personal and academic development. Consequently, a global improvement of results for the study cycle was expected.

This initiative, in addition to allowing a better integration of the new students, should enable the mentors to develop soft skills such as positive attitude, teamwork, leadership and communication skills that will be relevant for their future integration in the professional environment. A professor is assigned to monitor the performance of the mentor, assessing his difficulties, observing the progress of the students and giving advice to the mentor.

As referred, this programme was specially designed for students who, for the first time, attend the first year of the MIEC study cycle, and "often feel anonymous, insecure and isolated."[7] The success of the programme depends therefore, in a large measure, on the selected way to enhance the commitment of those students to their own achievements. It is then important that they are prepared, or helped, to share their expectations and difficulties and have an open mind to the hard and new challenges. An early diagnose of students difficulties and drawbacks is crucial to a prompt intervention.

Within a wishful thinking, one would expect that the new student is responsible and receptive to welcome help from the older colleagues.

Having these qualities as a behavioural basis, it will be expected that the new MIEC student acts as follows:

a) relates to older course students in a healthy and collaborative way;
b) understands the course's activities;
c) discusses and receives guidance on the most appropriate study methods;
d) gets help to access educational materials;
e) develops planning, teamwork and decision-making abilities;
f) feels encouraged to academic success.

It was accepted that would be very difficult to achieve such high standards and lots of work should be well done, under the right methodology, to come somehow close to that target.

4 METHODOLOGY

The methodology is about the way to find answers to research questions. In this programme, the raised questions were:

What is the effect of the mentors' intervention on the mentees?

Was the intervention programme helpful to different actors (mentors, mentees and teachers) of this programme?

To answer the first question, inquiries, interviews and direct questions were made in the begining and in the end of the experience. The results achieved in each year were an instrument to adjust the implementation programme for next years. Applying appropriate adjustments on the mentee and mentor relation, on metee and teacher relation as well as the performed activities, it was possible to improve the results during the last four years of experience. One of most relevant effect of the programme was the involvement of the new mentors, that were mentees in previous editions, by helping new students. These new mentors exhibit a complete identification with the programme and incorporation in communitie.

Concerning the second question, it can be said that important benefits were brought by programme granting a balanced transition between high school and university. The first-year students were able to quickly understand university organization and routine, get to know the campus and its infrastructures, and most of all, can easily contact and work with the pairs. It is also helpful an early stage integration process where direct contact between first-year student and teacher in charge of each team, helps to demystify pedagogical relationship paradigm, teacher-student. Contact with students from different academic years is also an advantage promoting academic community inclusion broaden the relationship between all the students, no matter the academic route.

5 IMPLEMENTATION

5.1 Starting up

Faced with the challenges referred as motivation for this project, the MIEC at FEUP, has implemented since the academic year 2015/2016, a programme to support new students, called CIVIL'in [9], which aimed to integrate and mentor the new first-year students by colleagues attending more advanced years.
CIVIL'in promotors were aware of the importance of this programme as a contribution to the recovery of Civil Engineering as honored field of knowledge and economy and to the encouragement of students who have not Civil Engineering as their first choice and may find a rewarding profession after all.
Since its first edition, the programme has a single mentor (one of the older students) assigned to the new student, who will accompany him from the beginning of the course until the end of the first academic year. Each mentor, sometimes working along with other first-year students, is always associated to a professor who gives him support and orientation to each of the mentor/mentee activities requested by the mentor/student and monitors the development of that association.
After four years of experience, this form of collaborative working still remains essential for CIVIL'in to fulfil the purposes for which it was established.
Procedures applied by the CIVIL'in programme, in the begining of each academic year, are meant to gather as soon as possible the good will of all participants, either mentees, mentors and academics.
The promotion of the programme was included, since 2016, in the school routines for the formal inscription of first year students. Professors and future mentors of the CIVIL'in team provide first information about the programme, enhancing the didactic, logistic and integration contributions to be delivered. Hard copies, online information and personal attendance in the CIVIL'in prepare the first year students to formalize their interest in participating in the CIVIL'in programme by filling an online application form.
Promotion continues throughout the academic year, with the presence of a CIVIL'in professor in first classes for the first year, a Facebook page, a web site, emails to every member of Civil Engineering, all these with updated information about CIVIL'in

activities and its availability to welcome new students (either mentors or mentees) to the programme whenever required.
Meanwhile, the first week is used to gather the candidates to mentoring as voluntary reinforcement of the working group from the year before.
In fact, unlike mentees, it is possible a selection and there is already a steady group of mentors with valuable experience in CIVIL'in, making easier a renovation with new volunteer colleagues. The distribution of the new first-year students of MIEC by the mentors is discussed between professors and mentors and ultimately decided by the responsible for coordinating the programme.
The Orientation and Integration Office of FEUP, that provides psychological support to every student of MIEC, was referenced by the organizing committee of CIVIL'in to promote most of the training sessions for the mentors, The Secretariat of MIEC has been supporting the remaining training sessions, all together developing skills of the candidates for mentors, so that they can guide the new students in the academic support. The Secretariat of MIEC, since 2016/17, completes this formation with guidelines to face administrative problems.
In order to offer to mentor students the acquisition of basic skills, these training sessions are provided in the following areas:

a) integration and academic success promotion;
b) school drop-out prevention;
c) well-being and mental health promotion;
d) depression and anxiety psychological intervention;
e) risk behaviour prevention;
f) transversal skills development (relational and behavioural);
g) new students' academic support.

It is welcome that a mentor should be able to bring to his activity with the mentees the following skills:

a) sense of liability;
b) wilful spirit on helping colleagues;
c) ability to develop working relationships.

Each mentor is responsible for a maximum of two students, depending on the number of course units (UC's) enrolled in each school year.
The performance of the mentor is monitored by an academic from MIEC, who promotes group spirit among the students and mentors under his/her responsibility, assesses the difficulties and progress observed, and gives adequate advice to the questions raised by each member of the team.
Meanwhile, the new first-year students of the MIEC must show his interest by filling a form that is available since second week. This form has evolved from a brief inquiry about general aspirations, trends and preferences, in the first edition of CIVIL'in, to an inquiry with more invasive (and optional) questions, regarding social issues as quality of lodging (familiar, hostel, etc.), meals routines and transportation to and from FEUP.

This wider information provides the increase of valid criteria to select the mentor and better follow the activity and progresses of the mentee, taking mainly in account his secondary background.

5.2 CIVIL'in working structure and coordination

There is a narrow liaison with the organs of the masters and the department, mainly with Monitoring Committee of Civil Engineering where CIVIL´in is represented since the beginning of the programme. The structure of the programme had, from the beginning, to be built around all its members: professors, mentors and mentees. The first difficulty to accept is that there are no strict rules for a mentoring programme to be built. From the experience of these four years, the main issue is to create a good environment for all participants.
The Coordinating Commission of CIVIL'in has three members who have executive attributions, namely coordination of groups, logistics and extracurricular activities conducts the meetings with about 10 other professors, the mentors and the mentees. The first one includes professors, mentors, once training sessions are concluded, and the mentees so far applied.
Routines are established and detailed, as far is possible, and formation of groups is defined. In fact, it is allowed that some of the groups are formed beforehand, a practice that has been accepted in the two last years. It saves time and has been assessed as giving good results.
Other decisions are taken about the use of the facilities allocated to the programme, frequency of meetings at different levels, along with less formalized contacts, drop-in services and other routines. The use of logistical support (books, copies, computers, ...) is also clarified for all the participants on the programme.
This kind of plenary meetings only take half-way of each semester, to make the point of the situation and adjustments if necessary.

5.3 Matching mentors with mentees

A lot has been written about the best way to find the correct match between the mentor and his mentee. In CIVIL'in, from the first edition, the will of a pair of those students to work together has been respected with good results. The other matchings have evolved from randomness, to the consideration of location of origin or residence, and finally by the analysis of inquiries about proximity in favourite hobbies or cultural trends, all this collected from voluntary surveys, both from mentors and mentees.
All these methods are arguable. In fact, even the pattern for group's organization (two mentors for one professor, two mentees for one mentor) is sometimes overruled. Most important is an open and honest attitude from all involved in the analysis of the work produced and goals to meet. It has happened, for instance, that a mentee, for practical reasons, has his mentor changed from first to second semester.
Another conclusion from the practice of these four years is that a student with high grades and an impeccable academic curriculum does not necessarily turn into the

best mentor. It was observed that students who have experienced difficulties in integrating the community of FEUP and some setbacks in their academic curricula often find in an easier way great empathy with first year students with similar profiles. Matching mentors and mentees remains as an open issue: their own will, origin or residence, favourite hobbies, all methods are arguable and broadly discussed by all members in advance. Additionally, to the formal and informal meetings between the elements of each team, other activities, combining leisure with civil engineering aspects, have been proposed, in each academic year. Along with the promotion of teamwork, these activities aim to complete the first year curriculum where science has a major role and there are not many opportunities to enter the world of Civil Engineering.

5.4 Daily groups work

The meetings of each team are scheduled by the professor and from there mentors and mentees arrange their own forms of collaborative work, including meetings in the CIVIL'in room and elsewhere, drop-in service in that room, emails or other kind of contacts.

The CIVIL'in room, available since 2017/18, is very useful as a platform for the activities of the programme and mentor's availability to help any mentee.

The activity of the group is supervised by the professor, to whom is committed the assessment of the quality of the performance towards the objective of the programme. This assessment and eventual interventions are fundamental in order to the success of the mentoring. In this process professors and mentors can learn from their experience and adjust their response to any difficulties that may occur.

A very critical point for the mentoring to be successful has arisen as the compromise between control and space left to the students to find themselves in the new environment. Surveys from mentees have given different sensitivities to this question in particular. For this problem, it was not found yet a general solution for the course. It was felt that different levels of flexibility were, in some cases, interpreted as diversity in the commitment demanded to mentees and even to theirs mentors.

5.5 Teamwork activities

Additionally, to the formal and informal meetings between the elements of each team, other activities have been proposed, in each academic year. Along with the promotion of teamwork, these activities aim to complete the first year curriculum where science has a major role and there are not many opportunities to enter the world of Civil Engineering. At the same time provide an enhancement of transversal relations.

The most interesting ones, in each academic year, were:

a) 2015/2016 - Development of a short film about the activities developed inside the Department of Civil Engineering (DEC).
   The goal of this contest was to make the new first year students know the Department of Civil Engineering. This knowledge did not consist only in the

exploration of the building where the DEC is located, but also in the history and the people who are part of that department.
Nine “short films” were produced in a friendly competition. The winners were the two ones that had the highest number of votes in a well-known site. At the end of this activity, a lunch was prepared to present all the films and present the winners.

b) 2016/2017 - Photography Contest "Where is the Civil Engineering".
In this activity, each team could submit to the competition a black & white or colour photograph where Civil Engineering works should be present. Two teams were winners in the following categories: black & white and colour.
The Photography contest allowed the new first year students to discover the city of Porto and to know better each element of his/her team, capturing through the lens an image of the beauty that Civil Engineering provides to our cities.

c) 2017/2018 – Workshop: Sustainable Construction.
This workshop was based on the theme of sustainable construction. The goal was to build small wall samples that used only sustainable materials (plastic bottles, glass bottles and cans), making them environmentally friendly and still performing their functions.
In this hand-on challenge the students could learn some concepts and processes, even not having plenty conscience of that, on a friendly and relaxed environment, where the spirit of teamwork and inter-help is evident.

d) 2018/2019 – Infrastructures in FEUP Campus
The students could observe various infrastructures related to Civil Engineering (foundations, drainage, water supply) and other branches of Engineering, mainly Electronics and Mechanics.

e) 2018/2019 – Visit to reservoir dams
The dams and hydroelectric centrals of Vilarinho das Furnas and Paradela were included in a round visit to the area of Gerês, some hundred kms north of Porto.

6 FOUR SEASONS EVALUATION

Throughout these four years, quotidian positive feelings build up among professors and mentors about the worth of the programme. However, it was necessary to get systematic information, mainly at the end of each semester, presumptively helping to evaluate the several aspects of the programme performance. Academic results were surely important indicators, but it is crucial to collect some information about other issues of the programme. In fact, feedback from professors, mentors and mentees are key elements to adjust the programme to requirements thus revealed.
Therefore, at the end of each semester, the new student is asked to fill in an evaluation form about his/her experience with CIVIL’in, namely referring the support got from the mentor, identifying the interest of this mentoring and possible aspects to improve, such as the use of facilities and other logistic issues.

Meanwhile, every mentor is asked to fill out surveys throughout the academic year in order to:

a) find out the work done by each group;
b) diagnose the strengths and weaknesses of the programme;
c) collect suggestions.

The surveys and evaluation sheets allow not only to assess individual performance, but also to assess the programme capacities.

6.1 Mentor performance evaluation

Considering the importance that this programme has in the development of extracurricular skills for the mentoring students, a mention in the “Supplement Diploma of the activity in CIVIL’in Programme - in-support for new MIEC students by their peers" is previewed to be assigned to mentors. However, they only have this mention if, at the end of the academic year, their final assessment is, at least, good, and they have the minimum attendance of not less than 90%.
For the “Supplement Diploma” assignment, in addition to the completed surveys, the mentor should also draw up a report, at the end of the academic year, about the results of their students, filling out a form for each student.
The academic (member of the CIVIL’in Commission) associated with each team, at the end of the academic year, appreciates the work carried out by each mentor, based on monitoring carried out throughout, in the evaluation sheets filled in by their students, in the answered surveys and in the final reports prepared by the mentor.
Based on the academic evaluation, the Commission responsible for the coordination CIVIL’in programme assigns a final grade. This assessment has been done under criteria that evolved from 2015 and are now the following, with these respective weights:

a) knowledge transmission capacity to new students – 30%;
b) developed skills (soft skills)-40%;
c) mentor reports– 30%.

Another benchmark is the attendance being considered by evaluation sheets filled in by their students and the academic associated with the mentor.
The ratings should be assigned according to the qualitative scale referred below.
Qualitative classification levels that appear in the “Supplement Diploma” correspond to quantitative ratings on a scale of 0 values to 20 values, as follows: bad – 0 to 7 values; Insufficient – 8 to 9; Sufficient -10 to 13; Good – 14 to 15; Very Good - 16 to 18; Excellent – 19 to 20 values.

6.2 CIVIL’in programme evaluation

The following results consider the evaluation of the programme in its four first years of implementation (2015-2016 to 2018-2019), obtained through the surveys and evaluation sheets filled in by the students and mentors. Fig. 1 presents the

frequencies of mentor requests to provide support to student(s) in the following areas: academic; FEUP services; UP services; integration and emotional.
The results show that support in solving academic problems was the most requested issue, followed by questions regarding the integration, the emotional and the FEUP services domains that have registered some concern.
It must be said that participation in surveys by mentees has been irregular, from more than 90 % in the first year to less than 30 % in 2016/2017 and 2018/2019, possibly those surveys were made available in the holiday period. In spite of this irregularity, there is a pattern of dominance of scores 4, in a scale between 1 and 5, as a global classification of the CIVIL'in programme.

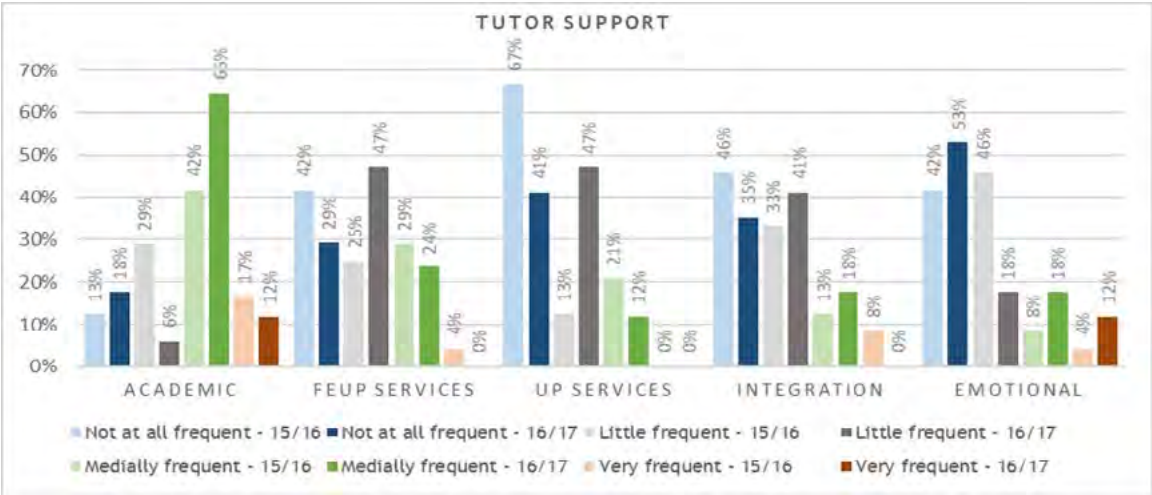

Fig. 1. Frequencies of tutor requests to provide support in different domains.

A few negative classifications, although the consideration of the programme as well structured, relied on insufficient activity and support by the assigned tutors.
According to the most severe evaluations, the CIVIL'in programme has a very positive purpose, but still some flaws.
Some of these appointed flaws have to deal with lacks in logistics and overall resources: gathering facilities, available equipment and hard copies for the course.
In student's surveys were also placed some questions that allow to assess the real needs of first-year students, determine the main obstacles to the tutor's good performance and gather suggestions for improving the CIVIL'in Programme functioning in upcoming editions.
Regarding the results of the tutors' inquiries, it can be observed that although more than 70% of the tutors have classified the programme with a score greater than or equal to 4 in the four years of the programme. There is at least one tutor, in the academic year 2016-2017, who has given a negative rating. The reason given by the tutor to assign this grade was the little (or no) initiative that the new first-year students had to seek help or even to belong to the programme.

In fact, there is already a large collection of the main issues (positive and negative), that have occurred in these four years. These data, conveniently treated and analysed, will be a growing and powerful tool to improve routines and behaviours.

6.3 Academic results

In higher education, it is unavoidable that academic results take a central role in the evaluation of the performance of learning activities.
The programme CIVIL'in had to be analysed from that point of view, comparing its performance in academic results and other important parameters, such as grade retention, of the CIVIL'in students, with those of the other first year students who did not join the programme.
For that comparison to be accurate as possible, a control group has been formed for each of the four seasons by a set with the same number of first year students as the CIVIL'in mentees. Trying to make that comparison as reliable as possible, and once the CIVIL'in students were known, the group of control was established by matching each one of the mentees to a colleague with an equivalent profile: marks of access, secondary school of origin, local of residence, Civil Engineering order of preference, as far as all this information was available. Protection data policies have made it more difficult and, for the last year of 2018/2019, only marks and order of preference were considered.
Meanwhile, both groups (mentees and control group) tended to be hit by dropouts, with more impact among the students out of the CIVIL'in programme. The table I reveals a clear difference, with advantage to the CIVIL'in group. One can argue the mentees start with more motivation taking in account their decision to join the programme. On the other side, it is not arguable that the immersion on a community based on solidarity has a protective effect on moments of disbelief or less interest for their job in the school.

Table 1. First year student's entries and dropouts

Academic Year	Total		CIVIL'in	
	Entered	Dropouts	Joining	Dropouts
2015/2016	159	40 (25%)	44	6 (14%)
2016/2017	171	47 (28%)	72	7 (10%)
2017/2018	153	21 (14%)	65	4 (6%)
2018/2019	204	51 (25%)	34	0 (0%)

The table I also reveals that the number of mentees decreased in 2018/19 in relation to the previous seasons and still there is not an accurate diagnosis for this occurrence. It may be that the decisive period for joining CIVIL'in was somehow more dispersive than usually by other activities for first year students.
On the other hand, it was the first time that there was not a single dropout within CIVIL'in. Does this mean that mentees, being in a less number, had more support

from tutors and mentees? Was the structure of the programme more reliable for that number of students? That is something to register and to be aware in next years.
At the end of 2nd semester, both groups have academic results and dropouts and, in what concerns comparisons, there was then a decision to make. Should the two groups be kept in their composition regardless dropouts or should the dropout elements be removed from the group of mentees and the control group be rebuilt accordingly?
This second option prevailed for two main reasons: the comparative results for CIVIL'in do not become improved (on the contrary) and it seemed more adequate to cross-check students who made all an equal route of challenges.
Comparative results are displayed in two bar charts. The first one shows (Fig. 2), in an expressive way, that CIVIL'in outstands in what concerns students with success in all 11 UC's (no failures) and still for those with 1 or 2 failures.

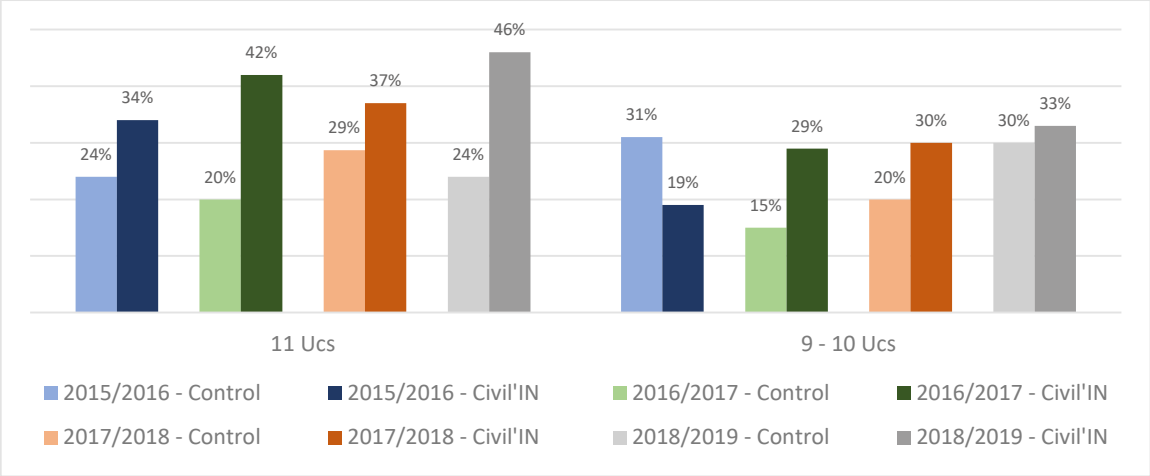

Fig. 2. CIVIL'in vs. control groups: 11 UC's (no failures), 9/10 UC's (1 or 2 failures)

Averaging through the four seasons, it can be seen that 40% of the CIVIL'in students were successful in all the 11 UC' s, achievement that lowers to 24% in the control group.
With success in 9 or 10 UC's, still considered a satisfactory performance, those numbers are respectively 28% and 24% and include an atypical reverse result in 2015/16.
The second bar chart (Fig. 3) reveals that, on the contrary of some hypothesis, the CIVIL'in work for success in every UC in not drawn to minimal goals and is not done at the expense of good marks for the better students. The most significant marks averages, for success in all 11 UC's, are slightly better for CIVIL'in students and quite equivalent when referred to success in 9 or 10 UC's.

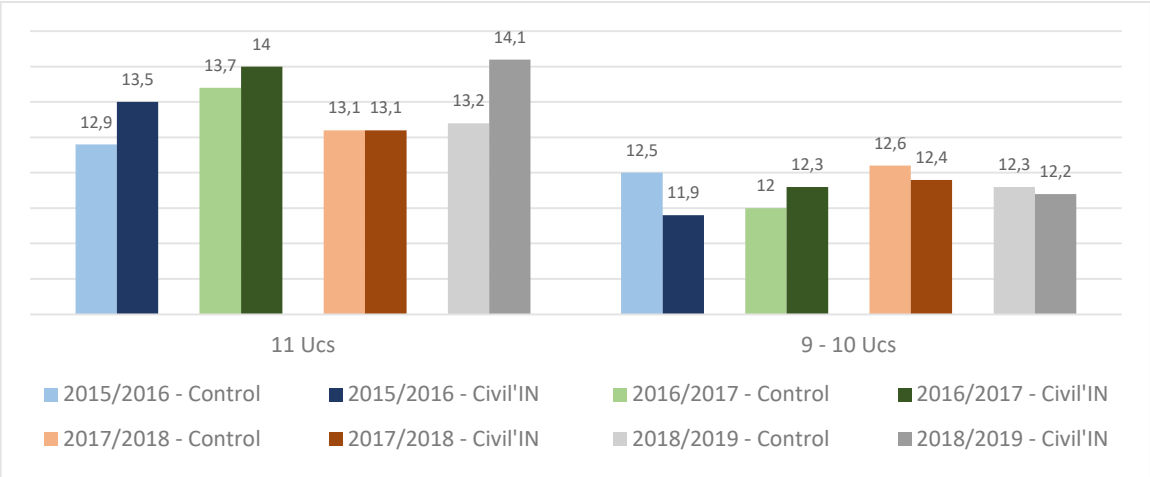

Fig. 3. CIVIL'in vs. control groups: average marks by most successful students

7 MENTORING IN FEUP AND UNIVERSITY OF PORTO

In the University of Porto, peer mentoring experience started at the Faculty of Sciences of Education and Psychology, in 2011/2012. It was followed a few years later, in 2015/2016 by the implementation of the programme CIVIL'IN in the Civil Department of FEUP. As the first experience in this faculty, as referred, and it was followed in successive years by the Department of Mechanics Engineering. and the Department of Chemical Engineering. Dealing with less students and high average grades (namely Mechanics), these two other programmes have both a single professor evolved, coordinating the activity of mentors and mentees.
Challenges are different, but there are common problems and solutions that have been shared. The Faculty, by its Pedagogical Council, has taken great interest in all three programmes, a FEUP Mentoring was created in December of 2018 to gather those experiences and it is already a reality on this new year (2019-2020) that all other engineering masters (Electronic, Metallurgical and Bioengineering) have started their own mentoring programmes.
Along with other peer mentoring experiences in other schools of the University of Porto (UP), CIVIL'in joined a proposal to the Direction of UP to create a network of mentories, taking acquired experiences to other schools of the university. An academic and scientific committee, where CIVIL'in is represented, was entitled by U.P. to promote peer mentory UP wide. Workshops and seminars are now being carried out in several schools.

8 CONCLUSIONS AND FURTHER STEPS

Since its first season, the programme CIVIL'in relies on basic structure with a single mentor (one of the older students) assigned to the new student, who accompanies him from the beginning of the course until the end of the first academic year. Each mentor, sometimes working along with other first-year students, is always associated to a MIEC professor who gives him support and orientation to each of the

mentor/mentee activities requested by the tutor/student and monitors the development of that association. After four years of experience, this form of jointed work still remains as essential for the CIVIL'in to fulfil the purposes for which it was stablished.

From academic results and other evaluations, it is clear that significant benefits were brought by the programme to the transition between high school and university. The arriving student feels that he can count on the support of a team that is able to help solving any problems in several fields, in promotion of their academic success, in the creation of favourable conditions for their personal and academic well-being and on forwarding difficult problems resolution to the competent services.

At an early stage of the integration process, the direct contact of the first-year student with the teacher in charge of the team is also very important since it helps to demystify the pedagogical relationship paradigm, teacher-student. In addition, the CIVIL'in programme fosters, from the beginning, the new student interaction with students of more advanced years, without being directly associated with hazing, proves to be an asset for a good adaptation process.

Taking into consideration the expressed opinions by students in surveys conducted during the programme and in addition to the meetings and get-togethers between the elements of each team, activities proposals to foster teamwork proved quite important landmarks in this process and should continue to exist in other editions.

Matching mentors and mentees remains as an open issue: their own will, origin or residence, favourite hobbies, all methods are arguable and broadly discussed by all members in advance. An interesting conclusion from the practice of these four years is that a student with high grades and an impeccable academic curriculum does not turn necessarily into the best mentors. It was observed that students who have experienced difficulties in integrating the community of FEUP and some setbacks in their academic curricula often find an easier way great empathy with first year students with similar profiles.

Additionally, to the formal and informal meetings between the elements of each team, other activities, combining leisure with civil engineering aspects, have been proposed, in each academic year. Along with the promotion of teamwork, these activities aim to complete the first year curriculum where science has a major role and there are not many opportunities to enter the world of Civil Engineering.

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DESIGNING AND ANALYZING OPEN APPLICATION-ORIENTED LABS IN SOFTWARE-VERIFICATION EDUCATION

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Keywords: *Application-oriented teaching, Software education, Complex Problem Solving*

ABSTRACT

The daily work of a software engineer frequently includes the design and implementation of systems in non-software-engineering disciplines, like medical technology, often in interdisciplinary teams. In order to successfully select and apply the appropriate theoretical concept to perform the task, it is necessary to understand the actual problem, possibly outside one's personal subject area, and to find an appropriate abstraction. However, software-engineering education often focuses on the theoretical concepts alone, ignoring the necessary skills to solve interdisciplinary tasks. We argue that the use of open, application-oriented labs creates a synergetic effect

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in understanding of theoretical concepts and the ability to apply them to solve practical issues. The subject of this study is a lab in the master's program module "Software Verification" at a German university of technology. Therein, student groups solve openly-formulated, application-oriented modeling tasks in the field of medical technology. In this paper, we present the design and an analysis of this lab by means of a student questionnaire after completion of the lab and a document analysis of 32 laboratory reports. Our survey results show that more than 90 % of the respondents state that the practical labs helped them to understand the theoretical content of the lectures. The evaluation of the lab reports shows that around half of the student groups were able to understand, abstract, and model the task correctly. We conclude that the inclusion of open, application-oriented labs in software-engineering education is beneficial to both, understanding of theoretical concepts and ability to solve interdisciplinary tasks.

1 INTRODUCTION

Digitalization brings software into more and more areas of our lives. Many of these areas are outside of computer science, where software enables other systems or processes to fulfill their tasks. These systems are built by interdisciplinary teams and require shared knowledge of the application domain [1]. In this work, we focus on the verification part of software development. The challenge in this context is to model the system at a working level of abstraction [2], formally specify the requirements, and then check the model against the specification using an appropriate algorithm. Fig. 1 shows the general workflow of complex, interdisciplinary problem solving in the area of computer science.

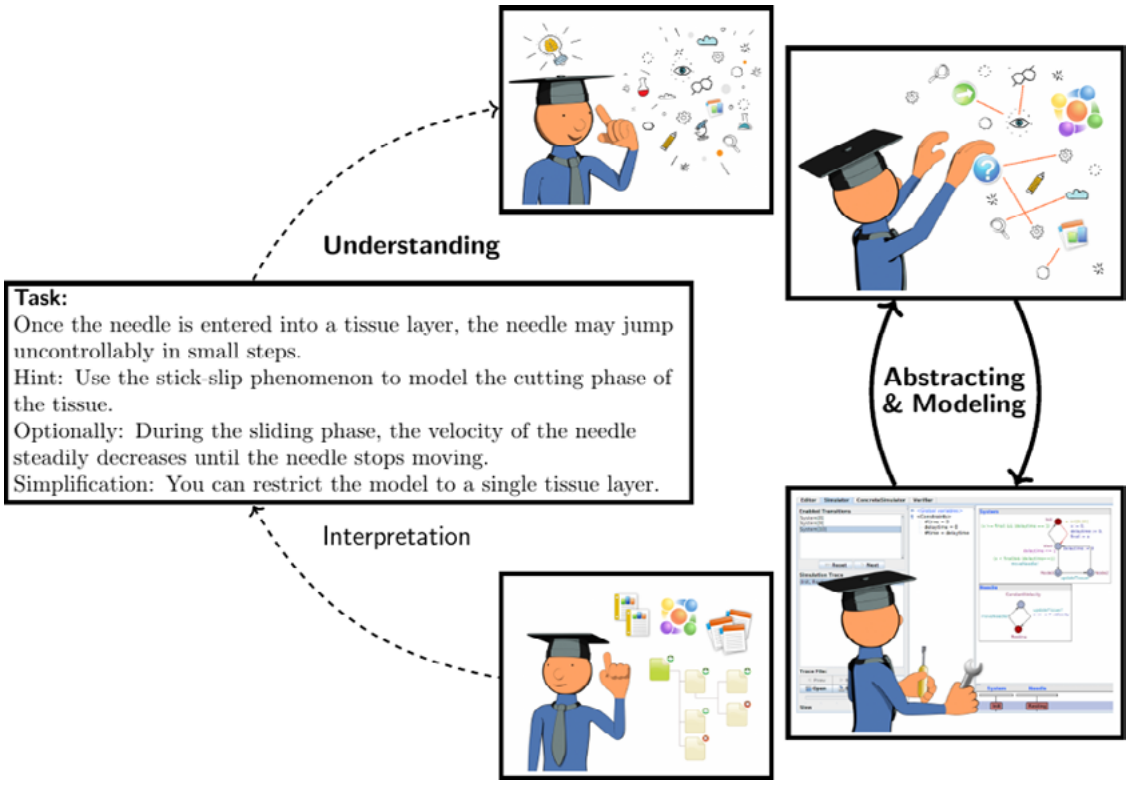

Fig. 1. Workflow of solving interdisciplinary issues

Preparing students for these tasks is a challenge for traditional software-engineering education. In traditional exercises, the students have to apply concepts learned in the lecture, but usually these pen-and-paper tasks are overly simple and already state which technique to apply. The students never have to consider which modeling formalism to choose or whether a detail should be included in the model or not.
To overcome this limitation, we introduce open, application-oriented labs. These labs require the students to solve authentic and complex problems [3] based on an ongoing research project in the field of medical technology, providing an interdisciplinary, real-world scenario. Although the required medical knowledge is simplified and already provided in the task description, the tasks foster the competence to quickly extract the required medical and mechanical knowledge. The students must understand the problem, choose one of multiple possible ways to solve it, and deal with some uncertainties. The open, application-oriented labs put an emphasis on engaging students in research and inquiry [4], providing moderately ill-structured and moderately multi-disciplinary projects as proposed for undergraduate tasks in complex problem solving [5]. Furthermore, these labs better align the teaching activities with the learning goals of the course [6], which include the competences to develop models, to select appropriate verification techniques, and being able to identify and formulate new problems in the field of software verification.
In addition to being a necessity for software verification, abstraction is a key skill for computer science in general. Students who are able to abstract are also able to handle complexity and to produce elegant models and designs, but students who lack the ability to abstract struggle with complexity and the identification of the important parts of a problem [7].
In this work, we address the questions whether open, application-oriented labs help students 1) to better understand the key concepts presented in the lecture, 2) to abstract the actual problem of open interdisciplinary problems, and 3) to apply the taught concepts to solve these problems. The context of our study is a course on software verification at a German university of technology. The remainder of this article is structured as follows: In section 2, we provide some background on the software-verification course and introduce the open application-oriented tasks. In section 3, we present our evaluation methodology, and the results are presented in section 4. Section 5 contains a discussion of the results before section 6 concludes.

2 COURSE DESIGN OF SOFTWARE VERIFICATION

In this section, we provide some background on the course and the newly introduced open application-oriented labs.

2.1 Course Organization

The course “Software Verification” is a partly mandatory, partly elective module in four master’s programs. While most of the students take it in the first, a few take it in the third semester.
After completing the course, students should, among others, know the major verification techniques. They should be able to formalize and solve verification problems

and to justify their work. Additionally, they should be able to conduct independent research and to present their results.
The course “Software Verification” runs for fourteen weeks. It consists of a weekly lecture, which covers the theoretical concepts and logical foundations [8, 9], and is accompanied by a weekly recitation section. The recitation sections consist of *lab sessions* to get familiar with the tools, *group works* to work on verification projects using the introduced tools, *question sessions* to ask questions concerning the lecture and verification projects, and *presentation sessions* to present the results of verification projects. Therein, students deepen their understanding in six traditional exercise sheets with pen-and-paper tasks and three new lab sheets designed as verification projects in groups called “open application-oriented labs.” This study focuses on lab 1. The modeling tasks of lab 1 should be solved with the tool UPPAAL [10]. The students submit the models together with a documentation and present their results to the other students. To pass the module software verification, the students have to pass the exam as well as to achieve at least five points in sum for the three labs. The lab achievements are awarded as bonus points to the exam results.

2.2 Open Application-Oriented Labs

The interdisciplinary tasks for the open application-orientated lab 1 were taken, with some simplifications, from a new interdisciplinary research project at the institute. It addresses the medical technology issue *needle steering* by using formal methods. Automated needle steering is a new attempt in medicine technology for minimally invasive procedures. A flexible needle delivers treatment to a specific target, which requires careful guidance of the needle. For lab 1, we derived an introductory exercise and five different modeling tasks from the complex process of needle steering. The application-oriented tasks include the following topics among others: deformation of tissue, needle divergence, and the distribution of treatments around a target. For each student group, the lab consists of the same introductory exercise and one of the five tasks. The introductory exercise provides a helpful basis, but is not a prerequisite for solving the tasks and offers a first modelling approach. We randomly assigned the tasks to the student groups. All tasks are comparable in terms of workload and require the implementation of a physical or mathematical law. All tasks consist of a short description of the application context, a hint of the physical/mathematical background, the main task, and an additional optional task (c.f. Fig. 1).
In the task design, we have deliberately chosen an open question formulation. In a research context, we are interested in new solution approaches and want to give free rein to the students’ creativity. We also want to impart the necessary skills to solve complex, interdisciplinary problems. In designing the open interdisciplinary task derived from current research activities, particular attention needs to be paid to leveling out complexity and students’ autonomy in engaging the students in research and inquiry [11].

3 COURSE EVALUATION

The application-oriented labs are a prototype of a new teaching approach. We integrated the complex, interdisciplinary elements into the course, and we are interested in evaluating how promising the new approach is. Our assumptions are that the application-oriented labs help students

1. to comprehend the key concepts of software verification lecture and
2. to understand the open interdisciplinary issue, to abstract the actual problem and to apply theoretical key concepts to solve it.

The two assumptions represent different perspectives on the challenge of dealing with interdisciplinary tasks. The first idea claims that the application-oriented tasks motivate students to engage with theoretical contents of the lecture so that they understand them. The second idea claims an inverse relationship: by applying lectured theoretical concepts to interdisciplinary problems, students learn to deal with open, interdisciplinary issues, which require to take a look into other research areas and a classification and definition of the actual problem.

3.1 Study Methodology

We used a mixed-methods approach to evaluate both assumptions: a student survey and a document analysis of 31 submitted lab reports.
The students of the module were asked to answer 17 questions concerning the lab via a self-designed online questionnaire, which was conducted after completing the presentations of the lab 1. The focus of the first 14 closed questions was the understanding and the level of difficulty of the open, application-oriented tasks, the understanding of theoretical contents by the labs, and the cooperation within the group. The possible responses were detected on a 4-point agreement scale (*strongly agree*, *agree* and *disagree*, *strongly disagree*). Three openly formulated questions asked for understanding of the theoretical contents of the lecture, difficulties, while processing the labs, and improvement suggestions. We opened the online survey for one month for all registered participants of the module. 20 students completed the questionnaire; thus, a quarter of the participants took part voluntarily. Their responses are part of the evaluation. Furthermore, we evaluated the 31 labs submissions. Our document analysis included the evaluation the 62 submitted models (31 on the introduction exercise and 31 on the application-oriented tasks) on their technical and content-related correctness and was done by one teacher of the course. We classified the submitted models in three categories *unsatisfactory (C)*, *satisfactory (B)*, and *more than satisfactory (A)) using unambiguous technical and physical criteria*. On the technical side, we checked whether the basic concepts of the theory of timed games were applied in the modeling artifacts. We have rated the tasks with a technical *B* if the basic concepts were implemented. Else, the groups got a *C*. Did the students also model further, more complex theoretical concepts beyond the basics, we rated the task with technical *A*. On the content-related side, we checked the realization of the required physical/mathematical law. We rated the task with content-related *B* if the idea was implemented correctly. Else, the students groups got a *C*. Did

the students also complete the optional task correctly, we rated the task with a content-related *A*. Of the introduction exercise we only checked the technical correctness, as the students were not asked to implement a physical or mathematical law. To evaluate assumption 1, we used the results of the survey regarding the understanding of theoretical concepts by the labs and the technical analysis of the submissions. The survey represents a self-assessment of the students, while our technical analysis of the models shows to what extent the students understood the theoretical contents based on solving the application-oriented labs. To evaluate assumption 2, we used the results of the survey regarding the understanding of the open, application-oriented tasks and the technical and content-related analysis of the models of the main tasks. On the basis of the survey, it can be classified whether *the students perceived the difficulty to understand the tasks*. While the analysis of the models shows the ability of the students to solve interdisciplinary problems.

3.2 Results

This section presents the results of the evaluation regarding assumption 1 and assumption 2.

The evaluation of the survey (see Fig. 2) and the document analysis (see Fig. 3) with regard to hypothesis 1 shows: Statement 4 *The practical exercises in the lab helped me to understand the theoretical content of the lecture* and Statement 5 *Solving an application-oriented task makes me more interested in the underlying theory were* replied by the overwhelming majority of the respondents with *strongly agree*/*agree* and barely with *disagree*/*strongly disagree*. Replies to the open formulated question 16 *Which topics of the lecture are possibly easier to understand after solving the task?* were: timed automata, guards, invariants, deadlocks, urgent and committed stages, model checking, logics and specification of properties. All mentioned keywords correspond to relevant theoretical concepts of the lecture. The results of the analysis of the 31 submissions concerning the correct implementation of theoretical concepts, regardless the content-related implementation, are: The introduction exercise and main task were completed of only a few groups unsatisfactorily *C*, with majority satisfactorily *B*, and of some groups more than satisfactorily *A*.

The evaluation of the survey and the document analysis with regard to assumption 2 shows: Half of the respondents replied *disagree* to statement 3 *I could easily understand the given tasks*, while the other half *agreed*/*strongly agreed*. The statement 7 *It was easy to solve the task based on lecture and tutorial* was *agreed*/*strongly agreed* by more than half of the respondents, while slightly less than half *disagreed*/*strongly disagreed*. In reply to open formulated question 17 concerning *the difficulties in solving the task*, the respondents stated inter alia: “Understanding the task problem. It was vague” and “More information could be provided for each task so that assumptions can be avoided”. The respondents also noted their difficulties with the tool UPPAAL.

Compared to the technical analysis of the 31 submissions of the tasks, the content-related analysis turned out worse: The tasks were completed by only slightly more than half of the groups satisfactorily or more than satisfactorily. Overall, 16 groups

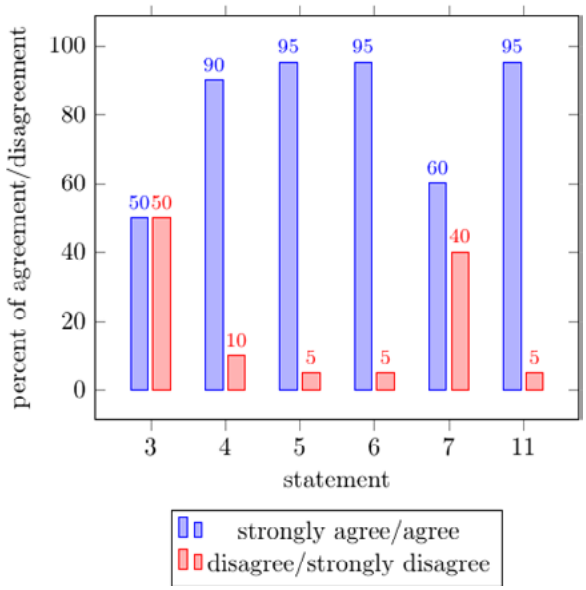

Fig. 2. Evaluation of the survey

fulfilled the task well in terms of content (content-related *A* or *B*) and applied the theoretical concepts correctly (technical *A* or *B*) as depicted in Fig. 4. In contrast, for 15 groups we rated either the technical, the content implementation, or both with a *C*. The content-related and technical evaluation is identical for 19 submissions (*AA*, *BB*, or *CC*). Furthermore, the analysis shows: None of the groups had completely diverging technical and content-related results, there is no combination of *A* and *C* in the overall evaluation of the submissions. In fact, the content-related parts correlate positively with technical parts: All groups with content-related *B* or *A* have at least a technical *B,* and only for one submission, the technical part is rated higher (with *A*) than the content-related part (with *B*). Further interesting findings of the survey are, that the overwhelming majority of the respondents agreed and strongly agreed with statement 6 *I enjoy solving the task* and statement 11 *I would appreciate to take more application-oriented tasks in the course*. The students' suggestions for improvement (question 18) were mainly related to the organizational realization of the labs. One student even replied explicitly: "Overall the labs were very good."

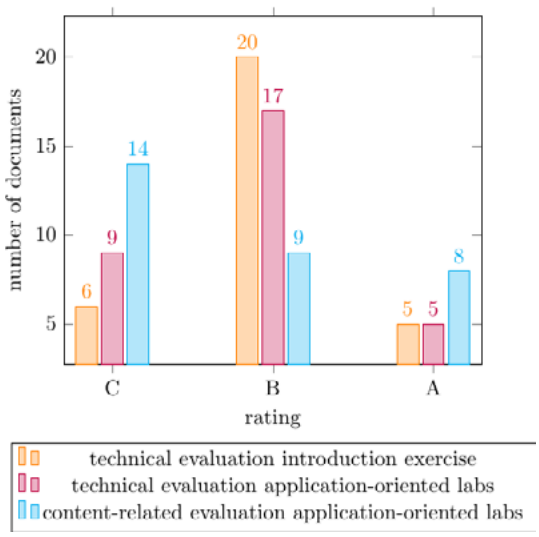

Fig. 3. Detailed Evaluation of lab submissions

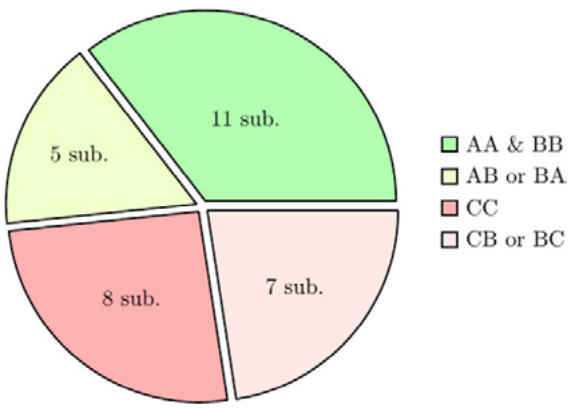

Fig. 4. Evaluation of application-oriented labs submissions classified according to their technical and content evaluation

3.3 Discussion

The self-assessment of the respondents as well as the analysis of models regarding the application of theoretical concepts confirm hypothesis 1: The application-oriented

labs help students to understand the key concepts of the software verification lecture. The number of unsatisfactory submissions of the main tasks is slightly higher compared to the introductory exercise. This is likely due to the different design of the tasks: for the introduction exercise a part of the solution has already been given to the students.

The survey and the analysis of the models confirm also assumption 2, but the results require a more detailed explanation. The results of statement 3 and 17 show: Understanding the task and abstracting the actual problem was a challenge for half of the respondents. This was exactly what we intended in order to teach students to deal with open interdisciplinary problems. Slightly more than half of the respondents stated, that it was easy to solve the tasks based on the lecture (statement 7). The analysis of the models reflects precisely this result. Slightly more than half of the submissions shows good and very good results. Furthermore, the technical evaluation of the tasks confirms: all except 6 groups were able to apply key concepts of the lecture to solve the open interdisciplinary problems. However, the content-related evaluation differs from the technical evaluation. The results show: the tasks were asked in a way, that the students were basically able to abstract and model the actual problem, see the 16 good and outstanding submissions. But correctly solving open issues in terms of interdisciplinary contents, e.g. implementing physical laws, is also a challenge for the students – see the 14 unsatisfactorily content-related submissions. However, good and excellent content-related results were always accompanied by good technical results. We can conclude from this that a good understanding of the underlying theory is a prerequisite for a successful solution of the task, which proofs that the tasks are well designed. Overall, the self-assessment of the respondents also confirms assumption 2: The application-oriented labs help students to abstract the actual problem of open interdisciplinary problems and to apply key concepts of the lecture to solve them. But the results also show, that solving the open application-oriented task, in particular the understanding of task, has not been easy for all students.

4 CONCLUSION

In this paper, we discussed the use of open application-oriented tasks in education to improve the comprehension of theoretical concepts and the competence to solve complex problems. For this purpose, we considered the course “Software Verification” at a German university of technology. The main challenge was teaching the ability to model systems from an interdisciplinary context at a level of abstraction that allows to successfully apply formal verification, one of the key concepts of the module software verification. We designed open application-oriented labs with an application context from medical technology to overcome this challenge. To evaluate the effect of the labs, we used a mixed-method approach of student questionnaires and an analysis of student-submitted lab reports. That confirmed our assumption that the open application-oriented labs help students to better comprehend the key concepts of the lecture as well as to be able to understand and abstract an open interdisciplinary problem and apply key concepts to solve it. But the results also confirmed that

some students have difficulties to work on open interdisciplinary issues. If we want to prepare students for professional life, then we need to integrate more teaching formats like research-based learning that potentially enable the acquisition of skills such as *complex and interdisciplinary problem solving*. The challenge is and remains to find the balance between challenging the better students and supporting the weaker students so that in the end all students acquire the competencies of understanding the subject-specific theories and learn to solve complex problems.
Open application-oriented labs are one promising way to overcome the bottleneck in teaching *complex, interdisciplinary problem solving* and also to awaken the interest in the theory. But in the implementation, it must be ensured that the weaker students receive suitable support to also solve such tasks successfully. This point remains open and will be addressed in future work.

5 ACKNOWLEDGMENTS

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EDUCATING THE NETFLIX GENERATION: EVALUATING THE IMPACT OF TEACHING VIDEOS ACROSS A SCIENCE AND ENGINEERING FACULTY

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Conference Key Areas: *E-learning, online learning, blended learning, virtual reality*
Keywords: *rich-media, video, student attainment, engineering*

ABSTRACT

In 2017, the Faculty of Science and Engineering at Manchester Metropolitan University began an initiative that led to the creation of over 2000 teaching and learning videos to support students across eight distinct STEM disciplines ranging from Engineering to Geography. The primary aim of the video initiative was to improve teaching metrics across the Faculty; specifically, around retention and progression. Student feedback on the videos via staff comments and student surveys has been consistently positive since the initiative began. However, evidence of the videos' direct impact on students' performance has until now not been measured. This paper reports the findings of the quantitative component of a mixed methods study to investigate the effectiveness of the video initiative on unit

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performance. Our sample consisted of 1248 first year and second year undergraduates (L4 and L5 in the UK). Whilst controlling for other factors, regression analysis revealed that viewing more videos, positively correlated with final unit mark. Although effect size was small, video view was the only significant contributor to improved unit performance besides entry qualification and ethnicity. When repeating the analysis to measure the probability of passing the unit, and of obtaining a good honours degree outcome, videos significantly improved the chance of getting a good honours degree but did not predict pass rates significantly.

A further qualitative study is now underway to investigate why, how and when students at Manchester Metropolitan make use of the video resources, and how students' use of video impacts on their learning and academic performance.

1. INTRODUCTION

Video and other forms of rich media materials are now an important part of higher education (Saunders and Hutt, 2014; Gillie et al., 2017). Video resources are either integrated into the Virtual Learning Environment as part of on-campus face-to-face courses or often form the main information-delivery mechanism in on-line courses. Multiple studies have shown that technology can positively influence learning (e.g., Means et al., 2010; Bernard et al., 2014), and that it can be a highly efficient educational tool (e.g., Allen and Smith, 2012; Rackaway, 2012; Stockwell et al., 2015). Taslibeyaz et al. (2017) conducted several case studies to show that watching videos was beneficial for changing attitudes, encouraging cognitive learning and retaining knowledge. Similarly, Yousef et al.'s (2014) review of qualitative and quantitative papers found some evidence that use of video-based learning saw improvements in teaching methods and learning outcomes.

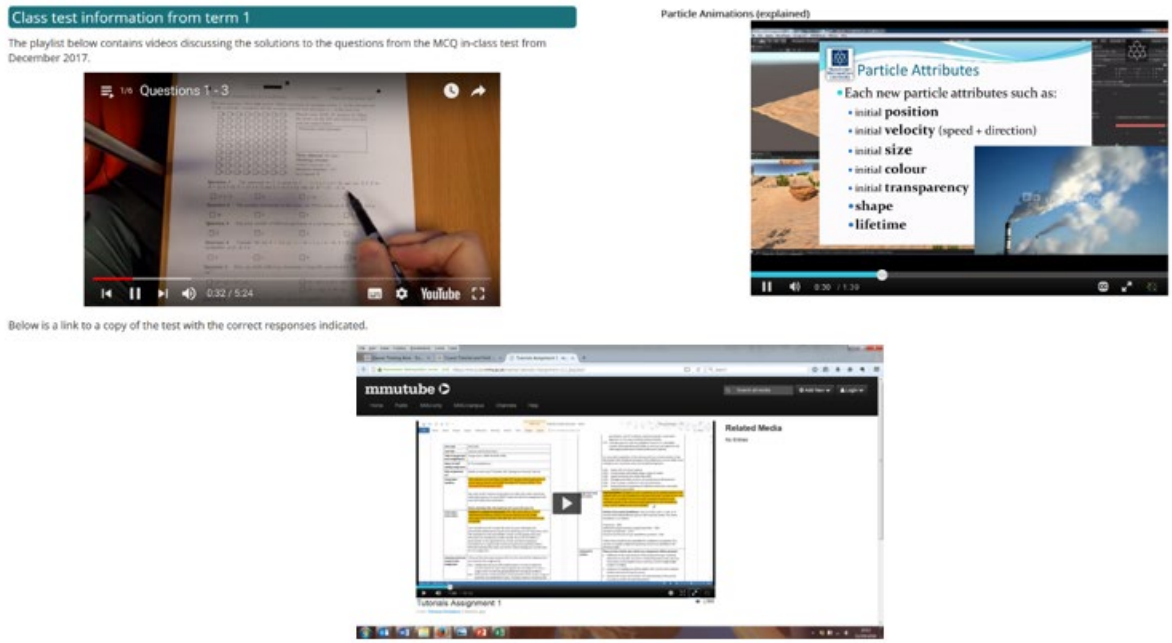
Video support, however, is not necessarily effective: Guo et al.'s (2014) study demonstrated that large segments of support videos are disregarded by students, while others argue that some videos contribute little to student performance (e.g. MacHardy and Pardos, (2015)). Furthermore, Dash et al. (2016) have shown that video support may not have the same value across all disciplines, but that it might be the best suited to illuminate abstract, hard-to-visualise phenomena and conceptual frameworks that are the foundation of STEM disciplines. Yet, there is no clear scientific consensus on what works for whom and in what circumstances, a question that this study begins to address.

The project began in 2017 in the Department of Engineering as a means of providing students with different ways of engaging with the core course material, of practising worked examples and revising at a time and place that worked for them. Since then, over 2000 videos have been made across the Faculty of Science and Engineering to support student learning and assessment. Our primary aim was to improve student performance at all levels of Undergraduate and Post Graduate Taught programmes, and to thereby increase rates of retention and progression across the Faculty. Secondary aims of the project were to improve the student learning experience and to offer increased flexibility in how and when students studied the course material. The videos were all designed and produced to be supplementary to existing on-campus face-to-face teaching, which is delivered primarily through lectures, seminars and laboratory classes. Short (5-7minute) videos were uploaded to the

Virtual Learning Environment. Videos were made on each unit for core concept explanations, worked examples of seminar problems, past examination solutions, and laboratory information and training videos. Assessment briefings and feedback videos were also added to the suite of videos across each unit. The videos are made by academic staff, and by students in some cases, using a variety of tools (e.g. Kaltura; PowerPoint; Explain Everything). Staff either talk over prepared slides or pdfs, often annotating as they go, or they may make a YouTube style video. The students could access the videos via the Virtual Learning Environment anytime thy wished- either before or after lectures or during revision for the examinations. The videos were not generally used as part of the lecture or seminar sessions.

Figure 1 below shows screenshots of three different types of video that were made; talking through solutions to an examination paper, explaining the concept of “particle attributes” in animation and talking through a coursework briefing document.

Figure 1. Exemplar videos made in the Faculty



Student feedback on the video support materials (via staff comments and student surveys) has been consistently positive since the initiative began in early 2017. Students have told us that the provision of videos improved their engagement with their course of study and that the videos help them better prepare for examinations and familiarise themselves more quickly with “hard to understand” or threshold concepts that are prevalent in Engineering, for example.

However, the evidence we have had up to now for the direct impact of the videos on student performance in a particular unit of study is empirically unproven. There is therefore a pressing need to find evidence for the effectiveness of video on student learning and performance. This is the primary contribution of this study.

Our aim was to investigate whether students' level of engagement with the videos impacted on their academic performance in a specific unit. To achieve this, student

cohorts enrolled to several units with video materials (in engineering, natural sciences, life sciences and computing) were compared to each other based on their level of engagement with videos. Regression analyses were applied that allowed us to assess the impact of video engagement when other key independent variables were neutralised. The analyses are then used to show whether the impact of video support on academic performance is significant and calculates the size of the effect through regression coefficients.

2. METHODOLOGY

Our study used a quantitative research design, which relied on secondary data exclusively from 8 units across the Faculty (4 first year and 4 second year units). Each selected unit had at least 80 enrolled students for academic year 2018/2019 and at least 5 videos (core concepts, exam paper solutions, coursework briefing etc) uploaded onto the Virtual Learning Environment (VLE). This gave us a sample size of 1442 students. Of those, we excluded those studying part-time (30) and those who did not engage with any VLE material in general (164). Final sample size was therefore 1248 students.

Our regression modes included multiple demographic characteristics and admission data of each student as a way of adjusting for (or accounting for) potentially confounding variables. The demographic data included the followings: gender, age, ethnicity, disability, socio-economic status (based on POLAR data, which is a geographically based UK measure of social and economic deprivation), and whether the student is registered as Home/EEA or overseas. Admissions data included the entry points and the level of study at entry (e.g. Vocational/A-level).

The outcome variable we used was academic performance (final unit marks). The independent variable of interest was the level of engagement with video materials, which was collected from the Institutional VLE. As the VLE only provides a binary information of views (e.g. someone viewed/did not view the material), a video engagement index was developed for each individual that shows the percentages of engagement (i.e. if a student engaged with 8 out of 20 videos, the index of 0.4 was assigned to the individual). The complete list of variables used in the study is shown in Table 1.

3. RESULTS

After establishing initial correlations and tendencies through descriptive and bivariate analyses, multivariate models were developed. Regression diagnostics were conducted to detect biases, based on the assumptions that (1) there is a linear relationship between outcome variables and predictors; (2) residuals are normally distributed; (3) no high correlations between independent variables; and (4) residuals are equally distributed (referred to as homoscedasticity) (5) no influential cases nor outliers.

Table 1. Complete list of variables used in the regression analysis

Independent variables

Variable Name	Level of measurement	Note
Level of Study	Nominal	*Level 4 (1st year undergraduate)/level 5 (2nd year undergraduate)*
Disability group (2-way)	Nominal	*Disabled/no disability*
First generaltion	Nominal	*Yes/no*
Gender	Nominal	*Male/Female*
Age	Nominal	*Young/Mature (mature students are those aged 21 or over)*
Overseas	Nominal	*Splits students based on fee status: Either Home/EU OR Overseas*
Entry Qual	Nominal	*Academic/Vocational: If students have at least one academic and no vocational qualifications (of equivalent size to an A level), they are classed as academic; if they have at least one vocational and no academic qualifications they are classed as vocational;*
Commuter	Nominal	*Commuter group is based on the students' term time postcode's distance from university (whether their travel time is more or less than 30 minutes) and their answers to the travel survey asked on enrolment*
Index of multiple Deprivation	Continuous	*POLAR4 quitile (most deprived neighbourhoods in UK)*
Ethnicity	Nominal	*White/BAME (Black and Asian Minority Ethnic)*
Above average Video views	Nominal	*above average/below average*
View / No view	Nominal	*Viewed at least one VSM (video support material)*
Video Engagement Index	Continuous	*standardised video engagement index was split by Units using z-score standardisation*

Dependent variables

Variable names	Level of measurement	Note
Final mark	Continuous	*standardised by unit*
70% or above (First Class Honours)	Nominal	*yes/no*
60% or above (Good Honours)	Nominal	*yes/no*
40% or above	Nominal	*yes/no*

3.1 Linear Regression – Unit Performance vs Video views

Multiple Linear Regression was run to assess hypotheses in relation to standardised unit marks. The model included the following predictors: video view, level of study, disability, first generation, age, entry qualification, clearing, commuting, multiple deprivation and ethnicity. The model produced $R^2 = .186$, $F(11, 784) = 17.51$, $p < .001$, suggesting that the model containing those predictors is significantly better than the one which does not rely on those predictors. Moreover, adjusted R^2 indicates that 18.6% of the variance in unit mark is explained by those predictors.

Regression coefficient results show that entry qualification ($b = .725$, $p < .001$) and ethnicity ($b = .311$, $p < .001$) act as the strongest predictors of unit mark. Video engagement also functions as a significant predictor of unit mark ($b = .110$, $p < .001$), whereas other factors do not predict unit performance significantly.

3.2 Logistic Regression – View/no View against Pass/Fail, above 60 and First

Logistic Regression analyses were also run to see whether viewing at least 1 video changes the likelihood of either passing the unit (requiring a mark of above 40%), or gaining a good honours grade (requiring a mark of 60% or above). The analysis included gender, entry qualification, ethnicity and view.

Findings suggest that looking at least one video does significantly improve the likelihood of getting an above 60% mark, and it is an even stronger predictor of getting a 1st class degree outcome (a mark of above 70%). However, it does NOT predict unit failure (a mark of below 40%) significantly. In other words, video support seemed to positively impact those students who are predicted to pass the unit but does not impact those who are about to fail on their units. Findings suggest that the better a student performs the more impact viewing video support materials have on their performance. The significant predictors are highlighted in bold in Table 2 below.

Table 2. Key predictors of unit performance

"40% or above" - prediction							
	coeff b	*s.e.*	*Wald*	*p-value*	*exp(b)*	*lower*	*upper*
Intercept	0.922	0.350	6.917	0.009	2.514		
GENDER (M=1)	-0.103	0.216	0.227	0.634	0.902	0.591	1.378
Entry Quals (Acad=1)	**1.659**	**0.227**	**53.366**	**0.000**	**5.254**	**3.367**	**8.201**
Ethnicity 2-way (White=1)	**0.455**	**0.218**	**4.337**	**0.037**	**1.576**	**1.027**	**2.418**
Viewed?	0.383	0.324	1.404	0.236	1.467	0.778	2.766

"60% or above (Good Honours)" - prediction							
	coeff b	*s.e.*	*Wald*	*p-value*	*exp(b)*	*lower*	*upper*
Intercept	-2.191	0.279	61.800	0.000	0.112		
GENDER (M=1)	**0.287**	**0.136**	**4.446**	**0.035**	**1.333**	**1.020**	**1.740**
Entry Quals (Acad=1)	**1.326**	**0.137**	**94.331**	**0.000**	**3.767**	**2.882**	**4.923**
Ethnicity 2-way (White=1)	**0.570**	**0.132**	**18.753**	**0.000**	**1.768**	**1.366**	**2.288**
Viewed?	**1.064**	**0.242**	**19.345**	**0.000**	**2.897**	**1.803**	**4.653**

"70% or above (First Class Honours)" - prediction							
	coeff b	*s.e.*	*Wald*	*p-value*	*exp(b)*	*lower*	*upper*
Intercept	-3.251	0.348	87.341	0.000	0.039		
GENDER (M=1)	**0.522**	**0.145**	**12.927**	**0.000**	**1.685**	**1.268**	**2.239**
Entry Quals (Acad=1)	**1.086**	**0.150**	**52.098**	**0.000**	**2.963**	**2.206**	**3.980**
Ethnicity 2-way (White=1)	**0.654**	**0.137**	**22.791**	**0.000**	**1.924**	**1.471**	**2.517**
Viewed?	**1.261**	**0.305**	**17.063**	**0.000**	**3.529**	**1.940**	**6.419**

4. DISCUSSION

As stated earlier, student engagement with and feedback on video support materials has been consistently positive since the initiative began in early 2017. Students had told us that the provision of videos improved their engagement with their course of study. In particular, the videos enabled students to prepare for examinations, better understand the coursework requirements and familiarise themselves more quickly

with “hard to understand” or threshold concepts that are prevalent across all Science and Engineering disciplines. Such findings are not new, having been already reported by (Bernard et al., 2014, Stockwell et al., 2015 and Taslibeyaz et al. 2017).

The primary contribution of this study, however, is to build on this emerging consensus that video helps student learning, to show a direct correlation between viewing videos and unit performance. Our findings provide new evidence to counter the view of MacHardy and Pardos (2015) that videos contribute little to student performance. Our study shows that, controlling for other factors such as ethnicity and entry qualifications, a correlation between students level of engagement with the videos and improved unit performance. Although effect size was small, video view was the only significant contributor to improved unit performance besides entry qualification and ethnicity.

Importantly, given the current focus on teaching metrics and good honours (a mark of 60% or above)) outcomes in the UK, this study also shows the correlation between viewing the videos and student performance is most pronounced at the 60% mark. When repeating the analysis to measure the probability of passing the unit (requiring a mark of 40% or above), getting a good honours (>=60%) or getting a 1st class mark (70% or above), our findings indicated that higher engagement with videos significantly improve the chance of getting a mark >60% and a mark above 70% , but does not predict whether students pass the unit.

However, these findings do need to be treated with caution, as correlation does not necessarily imply causation. One possible effect that we were not able to adjust for, is that better students will reach better results in general, and that more motivated students are usually also more motivated to watch and engage with the additional video support. In other words, we cannot be sure that there is a direct causal relationship between viewing the videos and unit outcomes, despite our regression analysis.

Nevertheless, these findings are important for educators, particularly in STEM disciplines such as Engineering, where concepts and frameworks can be abstract and difficult. Without a proper understanding of the theoretical building blocks of the discipline - the so-called threshold concepts (Meyer and Land, 2003) - students’ performance may be hindered and they may struggle to progress through their studies. Producing videos to support the teaching of engineering and other STEM disciplines can offer educators alternative ways of explaining concepts, practising worked examples and preparing students for assessment, which we have shown to correlate with improved unit performance. Additionally, by using video, educators can deliver their one best explanation to all students, available to view 24/7. Similarly, videos provide an alternative and additional means for students to engage with their studies, at a time and place which suits them as argued by (Matulich, Papp, & Haytko, 2008). With many of today’s students coming from widening participation backgrounds, and having more complex patterns of study (for example combining study with part-time working or caring responsibilities), the provision of additional support resources such as video has become even more important to enable students to continue and succeed in Higher Education. And, as the Covid-19 pandemic continues to run its course around the globe, it is likely that more and more students will require on-demand access to additional support resources such

as the types of videos described in this study, to help them progress successfully through Higher Education.

Whilst this study has shown a direct and positive correlation between students viewing the video resources and their unit performance, we now need to improve our understanding of why and how students used the videos. For example, what were the viewing/usage patterns for the videos?, which of the different types of video (examination solutions, assignment briefings, core concepts etc.) were most useful to students and why ?, and how did the videos compare to face-to face lectures and lecture captures as a tool for learning? Addressing these important questions will form the basis for the second part of this mixed methods study – a qualitative study based on student focus groups, which is currently underway.

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TOWARDS A TYPOLOGY IN LITERATURE STUDIES & REVIEWS IN ENGINEERING EDUCATION RESEARCH

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ABSTRACT

As the field of Engineering Education Research is maturing, more and more literature on Engineering Education is becoming available. Combined with increasing digitization and data analysis possibilities in the area of educational research literature, as well as a trend towards requiring more transparent and reproducible literature studies, researchers are required to adopt new and different approaches towards literature studies and reviews. Some examples of the different types are the systematic review, the critical review and the literature overview.

This paper intends to assist engineering education researchers by outlining a typology of different literature review types within the field of engineering education research. This typology is based on an elaborate analysis of published literature studies in 3 leading engineering education journals, the IEEE transactions on education, EJEE and JEE, making use of the SALSA Framework (Search, AppraisaL, Synthesis and Analysis) based on a SCOPUS search. A similar method has previously been successfully employed when creating a literature typology in health research by Booth and Grant in 2009 [1]. The characteristics of each typology will be described and suitable and relevant examples of each typology will be given. The outcomes presented in this paper will provide engineering education researchers with a valuable resource to conduct, inform, interpret and guide literature studies in their field.

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1 INTRODUCTION

1.1 Historical Perspective

Structural approaches to Engineering Education Research (EER) are relatively new. The first compendium on Engineering Education Research published by Heywood in 1985 [2] also does not refer to papers earlier than 1966. Even though the American Society for Engineering Education (ASEE) was founded in 1893, its flagship journal, the Journal of Engineering Education was only reconfigured into a pure scholarly journal in 1993. Its European sister organisation, the European Society for Engineering Education (SEFI), founded in 1973, did not launch its flagship journal, the European Journal of Engineering Education until 1985. Also, formal MSc and PhD degree programmes in Engineering Education were only launched in the U.S.A. from 2003 at Utah State University followed by Purdue and Virginia Tech in 2004 and Clemson University in 2006 [3]. In Europe, the UNESCO International Centre for Engineering Education at Aalborg University was the first to offer such a programme in 2004 [4]. This makes the field of EER a relatively young research field. From this perspective it is not strange that only in the last 10-15 years we see an increase in literature reviews on Engineering Education being published and a variety of review types emerging.

1.2 Literature Reviews

Although almost any scholarly article contains a section dedicated to literature, to show cause, relevance or need for the research reported on in the article, there is also the format of the review paper. In a review paper, typically a summary is given of the existing literature on a certain topic deemed relevant by the authors of the review with different purposes from justifying further research to providing readers with concise information. These papers are in great demand as with the increasing output of scientific publications, it is impossible for any scientist to read every paper in detail [5]. Over the last few years, systematic literature reviews in engineering education have become popular, spurred on by the 2014 article by Borrego, Foster and Froyd [6]. In their article they argue that literature reviews should mature to become more transparent in the research questions they address, where and how literature was searched for and what in- and exclusion criteria have been used.

1.3 Classification of reviews

Booth and Grant [1] show in their paper on the typology of reviews in health, that in that field many different types of reviews can exist. They identified 14 types of review, as listed in table 1. Their typology is predominantly defined by the intended aim of the paper, the audience for which it was intended, its scope and how the literature is searched, appraised, synthesized and analysed.
Within engineering education research, Borrego, Foster and Froyd [6] are so far the only ones who made a specific distinction. They distinguish, although allowing for overlap, between narrative reviews and systematic reviews. They define a narrative review as having an aim to synthesize or at minimum summarize prior work using often implicit identification methods and a systematic review having explicit

identification methods and characterized by a search, select, code and synthesis approach. Within they distinguish subtypes based on the analysis method (qualitative or quantitative) of the review and the reviewed papers. The overlap between both types, as stated by Borrego, Foster and Froyd [6], shows how difficult it is to make clear distinction between each type of review. It is impossible to create a taxonomy which would create distinctive separate groups like a family tree. Hence, the approach of Booth and Grant [1] is opting to stay with the principle of a typology, which allows overlaps in characteristics, working from the principle of concepts.

This difference in approach to reviews poked the curiosity of the authors. How similar are the types of review articles in engineering education? Do all types still occur? Are there different, new types to be defined? If so, is it possible to create a similar typology for engineering education research? To start this journey the authors looked at literature reviews published in a limited number of journals and to see what overlaps with Booth and Grant list exist.

Table 1. 14 typologies as defined by Grant and Booth [quoted verbatim from 1]

Name	Description
1.Critical review	Aims to demonstrate writer has extensively researched literature and critically evaluated its quality. Goes beyond mere description to include degree of analysis and conceptual innovation. Typically results in hypothesis or model.
2.Literature review	Generic term: published materials that provide examination of recent or current literature. Can cover wide range of subjects at various levels of completeness and comprehensiveness.
3.Mapping review/ Systematic map	Map out and categorize existing literature from which to commission further reviews and/or primary research by identifying gaps in research literature.
4.Meta-analysis	Technique that statistically combines the results of quantitative studies to provide a more precise effect of the results.
5.Mixed studies review/ Mixed methods review	Refers to any combination of methods where one significant component is a literature review (usually systematic). Within a review context it refers to a combination of review approaches for example combining quantitative with qualitative research or outcome with process studies.
6.Overview	Generic term: summary of the [medical] literature that attempts to survey the literature and describe its characteristics.
7.Qualitative systematic review/ Qualitative evidence synthesis	Method for integrating or comparing the findings from qualitative studies. It looks for 'themes' or 'constructs' that lie in or across individual qualitative studies.
8.Rapid review	Assessment of what is already known about a policy or practice issue, by using systematic review methods to search and critically appraise existing research.
9.Scoping review	Preliminary assessment of potential size and scope of available research literature. Aims to identify nature and extent of research evidence (usually including ongoing research).
10.State-of-the-art review	Tend to address more current matters in contrast to other combined retrospective and current approaches. May offer new perspectives on issue or point out area for further research.
11.Systematic review	Seeks to systematically search for, appraise and synthesis research evidence, often adhering to guidelines on the conduct of a review.

12.Systematic search and review	Combines strengths of critical review with a comprehensive search process. Typically addresses broad questions to produce 'best evidence synthesis'.
13.Systematized review	Attempt to include elements of systematic review process while stopping short of systematic review. Typically conducted as postgraduate student assignment.
14.Umbrella review	Specifically refers to review compiling evidence from multiple reviews into one accessible and usable document. Focuses on broad condition or problem for which there are competing interventions and highlights reviews that address these interventions and their results.

2 METHODOLOGY

2.1 Review paper selection

The authors opted to start this process with a systematized review as listed in table 1. They selected three high ranking engineering education journals as input for this typology attempt: the European Journal of Engineering Education (EJEE), the Journal of Engineering Education (JEE) and IEEE Transactions on Education (ToE). Using Scopus, a keyword search was carried out requiring the words "Literature" or "Review" to appear in the title, abstract or keywords for each journal on 17 March 2020. Although this may not be sufficient to catch all literature review papers published in these journals, it is expected to be sufficiently selective to be representative. This search resulted in 153 articles for EJEE, 107 articles for JEE and 157 articles for IEEE.

These lists were subsequently examined by the first author who read through each abstract and eliminated all non-literature review papers based on the abstract. As the authors did not have access through their institution to EJEE and JEE articles prior to 1995, and no literature review articles were identified in the search prior to 2000 in either journal nor in the search of ToE, it was decided to limit all articles to 2000 as a safe lower limit. The remaining 63 papers were then examined in more detail. All papers that were not a stand-alone literature review were eliminated as well as any reviews of software and standards. This resulted in nett lists of 14 articles for EJEE, 16 articles for JEE, and 7 articles for ToE published between 2003-2020, totalling 37 articles. The notion by Borrego et al. [6] that literature review articles in this young field are still rare can be confirmed. As can be seen in Fig. 1, most standalone literature reviews identified were published in the last 10 years.

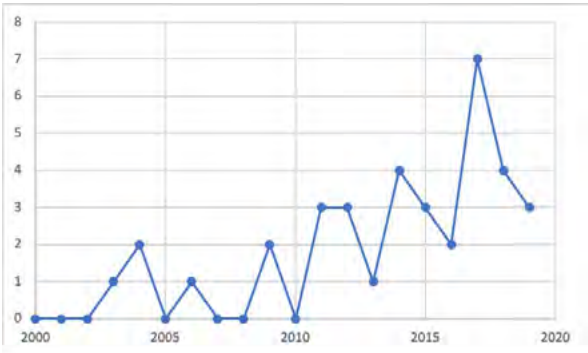

Fig. 1. Number of stand-alone review articles published in JEE, EJEE and ToE

2.2 Classification

The remaining papers were then read by the first author who for each paper recorded the aim of the paper; what review label, if any, the author of the examined paper assigned themselves and what the purpose of the review was. Based on this overview, the authors attempted to assign a typology from the list by Booth and Grant. To assist them in selecting the best typology the same SALSA framework, (Search, AppraisaL, Synthesis and Analysis) as employed by Booth and Grant [1] was used to characterize each paper. All papers included in this study are listed in Appendix A.

2.3 Limitations

The approach used in this paper has the following limitations. Firstly, the selection of search terms may mean that some literature reviews may have inadvertently been missed. Not all abstracts were sufficiently detailed and the authors were grateful for the available structured abstracts as this greatly assisted them in their search and appraisal. Secondly, only 3 engineering education journals were examined, even though the Research in Engineering Education Network (REEN) lists many more engineering education journals and also no proceedings of engineering education conferences were included which means certain types of reviews may have been overlooked altogether. Finally, the search and appraisal process for this paper would have gone more smoothly if better keywords, controlled and uncontrolled vocabularly terms were used by journals. Often literature reviews could not be identified from these, hindering the speed and accurateness of the process.

3 RESULTS

3.1 Classification analysis

All papers were initially analysed and qualified as described in section 2.2. In appendix A all articles are listed with their typologies. In table 2 the results are shown for the classifications given by the author to their review, either in the title or in the text. It can be seen from this table that there are two predominant review types: the systematic review and the literature review. Some of the other types listed can also be found in Booth and Grant [1]. These have all been marked by *.

*Table 2. Results of self-classification by authors of examined papers. Papers marked with * indicate review types listed by Booth and Grant [1].*

Classification	Number of articles	References
Systematic Review*	12	[7], [8], [9], [17], [18], [24], [26], [27], [29], [30], [34], [38]
(literature) Review*	11	[11], [14], [15], [19], [20], [21], [22], [25], [31], [36], [41]
Meta-Analysis*	2	[33], [43]
Survey	2	[37], [39]
Synthesis	2	[10], [42]
Critical Review*	1	[13]
Historical review	1	[32]
Literature Analysis	1	[16]

Meta-Literature Review	1	[35]
Narrative Review	1	[28]
Qualitative Systematic review*	1	[23]
Systematic Mapping Study*	1	[40]
None given	1	[12]

To see if the review types not listed by Booth and Grant were new types, all papers were also analysed according to the typologies described by Booth and Grant. In table 3 the results of this qualification are shown.

Table 3. Results of classification analysis using Booth and Grant's typology [1]

Typology	Number of articles	References
1.Critical review	6	[16], [28], [31], [35], [36], [41]
2.Literature review	8	[11], [12], [13], [14], [15], [22], [25], [32]
3.Mapping review/ Systematic map	2	[10], [29]
4.Meta-analysis	2	[33], [43]
6.Overview	4	[19], [20], [37], [39]
7.Qualtitative Systematic Review	1	[23]
9.Scoping Review	1	[40]
10.State-of-the-art review	1	[21]
11.Systematic review	12	[7], [8], [9], [17], [18], [24], [26], [27], [30], [34], [38], [42]

From the results in table 3, it can be seen that it was possible to classify all review within the typology of Booth and Grant. The systematic review was found to be the most popular type of review, followed closely by the literature review and the critical review.

3.2 Other observations

Out of the 37 review papers only one referred to the paper of Booth and Grant as a source of review types to select from. Most of the authors of the examined papers do not mention why they select a review method, and those who do predominantly have opted to use a systematic review and quote Borrego, Foster and Froyd [6] as the reason. Also, only nine of the review types identified by Booth and Grant were found in the papers. This is not to say that the other types of reviews do not (yet) exist in engineering education research. The purpose of some of the other typologies listed in Booth and Grant may preclude them from being published in these particular journals and may be more suited for publication in other journals or have only been published in conference papers and proceedings. Others, such as the reviews of reviews – the Umbrella review - may not yet have appeared as there are insufficient similarly themed systematic reviews to base these on. It can be expected that this type of review together with the qualitative systematic review and the meta-analysis will become more prevalent in the next few years.

A final observation is that the ToE has published less literature reviews than the EJEE or the JEE. This may in part be due to the scope of the journal and in part because the strict page limit (6 pages after which charges apply) may make the journal less attractive for the usually more elaborate review papers.

4 SUMMARY AND FUTURE RESEARCH

The typology as used by Booth and Grant appears to be inclusive enough to also be used in engineering education research. It goes further than the classification based on methods only as proposed by Borrego, Foster and Froyd [6] and may therefore be more conductive in use. To investigate this further more engineering education literature must be examined. This should include the engineering journals as listed on the REEN website as well as the papers published in the proceedings of the major engineering education (research) conferences such as ASEE and SEFI. It would also be worthwhile to investigate if other typologies of literature reviews exist in the general field of education as well as other fields to ensure completeness. Also, the authors echo the call by Booth and Grant [1] in their paper for the need of “an internationally agreed set of discrete, coherent and mutually exclusive review types” to assist researchers in any field.

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APPENDIX A: OVERVIEW OF CLASSIFIED LITERATURE REVIEWS

Title	Authors	Journal	Year	Volume, pages, doi	Self-Classification	G&B classification [1]
The study of grit in engineering education research: a systematic literature review [7]	Direito, I., Chance, S., Malik, M.	EJEE	2019	10.1080/03043797.2019.1688256	Systematic Review	Systematic Review
Evaluation of competency methods in engineering education: a systematic review [8]	Leandro Cruz, M., Saunders-Smits, G.N., Groen, P.	EJEE	2019	10.1080/03043797.2019.1671810	Systematic Review	Systematic Review
A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement [9]	Morelock, J.R.	EJEE	2017	42 (6), pp. 1240-1262	Systematic Review	Systematic Review
Explaining student success in engineering education at Delft University of Technology: a literature synthesis [10]	van den Bogaard, M.	EJEE	2012	37 (1), pp. 59-82	Literature Synthesis	Mapping review
Towards characterising design-based learning in engineering education: A review of the literature [11]	Puente, S.M.G., van Eijck, M.V., Jochems, W.	EJEE	2011	36 (2), pp. 137-149	Literature Review	Literature Review
Demarcating advanced learning approaches from methodological and technological perspectives [12]	Horváth, I., Peck, D., Verlinden, J.	EJEE	2009	34 (6), pp. 465-485	None given	Literature Review
Learning theories and assessment methodologies - an engineering educational perspective [13]	Hassan, O.A.B.	EJEE	2011	36 (4), pp. 327-339	Critical Review	Literature Review
Fostering creative engineers: A key to face the complexity of engineering practice [14]	Zhou, C.	EJEE	2012	37 (4), pp. 343-353	Literature Review	Literature Review
Why research-informed teaching in engineering education? A review of the evidence [15]	Bubou, G.M., Offor, I.T., Bappa, A.S.	EJEE	2017	42 (3), pp. 323-335	Literature Review	Literature Review
About, for, in or through entrepreneurship in engineering education [16]	Mäkimurto-Koivumaa, S., Belt, P.	EJEE	2016	41 (5), pp. 512-529	Literature Analysis	Critical review
The use of motivation theory in engineering education research: a systematic review of literature [17]	Brown, P.R., McCord, R.E., Matusovich, H.M., Kajfez, R.L.	EJEE	2015	40 (2), pp. 186-205	Systematic Review	Systematic Review
An overview of game-based learning in building services engineering education [18]	Alanne, K.	EJEE	2016	41 (2), pp. 204-219	Systematic Review	Systematic Review
New trends in web-based learning: Objects, repositories and learner engagement [19]	MacLaren, I.	EJEE	2004	29 (1), pp. 65-71	Review	Overview
A review of literature on employability skill needs in engineering [20]	Markes, I.	EJEE	2006	31 (6), pp. 637-650.	Literature Review	Overview
A retrospective on undergraduate engineering success for underrepresented minority students [21]	May, G.S., Chubin, D.E.	JEE	2003	92 (1), pp. 27-39	Literature Review	State-of-the-Art Review
Does active learning work? A review of the research [22]	Prince, M.	JEE	2004	93 (3), pp. 223-231	Review	Literature Review
Boundary Spanning and Engineering: A Qualitative Systematic Review [23]	Jesiek, B.K., Mazzurco, A., Buswell, N.T., Thompson, J.D.	JEE	2018	107 (3), pp. 380-413	Qualitative Systematic Review	Qualitative Systematic Review

Entrepreneurship Assessment in Higher Education: A Research Review for Engineering Education Researchers [24]	Huang-Saad, A.Y., Morton, C.S., Libarkin, J.C.	JEE	2018	107 (2), pp. 263-290	Systematic Review	Systematic Review
A Review of Competency-Based Learning: Tools, Assessments, and Recommendations [25]	Henri, M., Johnson, M.D., Nepal, B.	JEE	2017	106 (4), pp. 607-638	Review	Literature Review
Engineering Thinking in Prekindergarten Children: A Systematic Literature Review [26]	Lippard, C.N., Lamm, M.H., Riley, K.L.	JEE	2017	106 (3), pp. 454-474	Systematic Review	Systematic Review
What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review [27]	Passow, H.J., Passow, C.H.	JEE	2017	106 (3), pp. 475-526	Systematic Review	Systematic Review
Systematic literature reviews in engineering education and other developing interdisciplinary fields [28]	Borrego, M., Foster, M.J., Froyd, J.E.	JEE	2014	103 (1), pp. 45-76	Narrative Review	Critical Review
What is the state of the art of systematic review in engineering education? [29]	Borrego, M., Foster, M.J., Froyd, J.E.	JEE	2015	104 (2), pp. 212-242	Systematic Review	Mapping Review
Engineers at Play: Games as Teaching Tools for Undergraduate Engineering Students [30]	Bodnar, C.A., Anastasio, D., Enszer, J.A., Burkey, D.D.	JEE	2016	105 (1), pp. 147-200	Systematic Review	Systematic Review
Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies [31]	Borrego, M., Henderson, C.	JEE	2014	103 (2), pp. 220-252	Review	Critical Review
Hybrid Learning: An integrative approach to engineering education [32]	Jamison, A., Kolmos, A., Holgaard, J.E.	JEE	2014	103 (2), pp. 253-273	Historical review	Literature Review
The impact of flipped classrooms on student achievement in engineering education: A meta-analysis of 10 years of research [33]	Lo, C.K., Hew, K.F.	JEE	2019	108 (4), pp. 523-546	Meta-Analysis	Meta-Analysis
Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review [34]	Borrego, M., Karlin, J., Mcnair, L.D., Beddoes, K.	JEE	2013	102 (4), pp. 472-512	Systematic Review	Systematic Review
The informed design teaching and learning matrix [35]	Crismond, D.P., Adams, R.S.	JEE	2012	101 (4), pp. 738-797	Meta-Literature Review	Critical Review
Engineering instructional development: Programs, best practices, and recommendations [36]	Felder, R.M., Brent, R., Prince, M.J.	JEE	2011	100 (1), pp. 89-122	Literature Review	Critical Review
A survey and evaluation of simulators suitable for teaching courses in computer architecture and organization [37]	Nikolic, B., Radivojevic, Z., Djordjevic, J., Milutinovic, V.	ToE	2009	52 (4), art. no. 4967893, pp. 449-458	Survey	Overview
A Systematic Literature Review on Teaching and Learning Introductory Programming in Higher Education [38]	Medeiros, R.P., Ramalho, G.L., Falcao, T.P.	ToE	2019	62 (2), art. no. 8447543, pp. 77-90	Systematic Review	Systematic Review
Approaches and tools used to teach the computer input/output subsystem: A survey [39]	Larraza-Mendiluze, E., Garay-Vitoria, N.	ToE	2015	58 (1), art. no. 6777580	Survey	Overview
Cloud Computing for Education: A Systematic Mapping Study [40]	Baldassarre, M.T., Caivano, D., Dimauro, G., Gentile, E., Visaggio, G.	ToE	2018	61 (3), art. no. 8283623, pp. 234-244	Systematic Mapping Study	Scoping Review
Review of computer vision education [41]	Bebis, G., Egbert, D., Shah, M.	ToE	2003	46 (1), pp. 2-21	Review	Critical Review

The Underrepresentation of Women in Computing Fields: A Synthesis of Literature Using a Life Course Perspective [42]	Main, J.B., Schimpf, C.	ToE	2017	60 (4), art. no. 7953503, pp. 296-304	Synthesis	Systematic Review
Preparing ICT Graduates for Real-World Challenges: Results of a Meta-Analysis [43]	Pažur Aničić, K., Divjak, B., Arbanas, K.	ToE	2017	60 (3), art. no. 7795180, pp. 191-197	Meta-Analysis	Meta-Analysis

THE 'A-STEP 2030' PROJECT AND ENHANCING ENGAGEMENT IN ENGINEERING EDUCATION

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Conference Key Areas: *Interdisciplinary engineering education, linking different disciplines both inside and outside engineering, linking with society.*
Future engineering skills and talent management.
Keywords: *attractiveness, engineering education, future needs, sustainability, diversity*

ABSTRACT

The 'A-STEP 2030' project involves academic partners from Denmark, Finland, France and Ireland, with additional key inputs from Belgium (SEFI and BEST) and Sweden (Universum). The results were extracted from an extensive data-base of students' preferences in making future career choices, what they are willing to learn, what skills needed to be improved, and how they perceive the engineering profession and their ideal future employer. Particular note was taken of the similarities and differences between engineering and humanities students, male and female engineering students and students of different generations. Additionally, a survey of 16-year-olds was made, to improve the understanding of the younger generation. Students' own considerations were collected from symposia organised by BEST. The authors are writing this from their role as external advisers and the activity project leader. The results show interesting diversity.This gives a sound foundation for the next stage of the project, where attractive modules for engineering education will be created. These and other interesting emerging results will be discussed in the context of "How are the values and career goals of diverse students reflecting the future needs of education to establish a working life with sustainable goals?".

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1 INTRODUCTION

1.1 Motivation

Attractiveness of engineering education is a key element when we are trying to share a wide understanding of the effective methods with which to build sustainable global futures [1] & [2]. Continuing growth of welfare facing the United Nations 17 Sustainable Development Goals (SDG) needs advanced engineering solutions and extensive knowledge from people with diverse background. But how to attract people who have deep doubts, expectations that engineering drives the world to wrong direction - or that engineering is too difficult and boring.

1.2 Action

To define steps for more attractive engineering education the 'Attractiveness' working group of SEFI decided two years ago to establish a project combining research, surveys, workshops, focus groups and communication amongst the engineering education society and in working life. The aim of the project was to create concrete activities, tools, materials and methods to help the educators with their work.

The first step was to convene motivated partners. It was understood that to find innovative solutions diverse partners were needed. The core set of partners included a company undertaking research of students' motivation, appreciation and expectations, four academic institutions who were providing engineering education, a European organisation for engineering education and a European organisation of engineering students.

The second step was to create a project proposal - and finding a source of finance for it. Fortunately ENSTA Bretagne was able to offer a grant to enable the project partners to work together with the proposal [3]. This made it possible to obtain Erasmus + funding and to start working.

2 METHODOLOGY

2.1 Roles of diverse partners

The base of the methodology of the project was to define how to guarantee that a breadth of knowledge and diverse opinions would be included - and thus the work would not be done amongst the "believers".

The solution had several steps.
- Firstly, to understand the whole background, the university researchers had to undertake a literature review and build the academic framework for the project [4].
- Secondly to understand the present situation, statistically relevant data of students from all of the participating countries was needed. The company, Universum has

collected opinions from tens of thousands of students - and it was decided to use the data concerning engineering students and for comparison students of humanities [5].
- Thirdly the statistical data needed to be analysed by several stakeholders. This included a large number of focus groups with students, industrialists and academics in different countries, together with workshops and reviews by the advisers [5].
- The fourth step was to collect ideas about competences and ways to develop them to feed the fifth step, where different pedagogical solutions would be defined and some concrete courses created.
From these steps the project plan was put together and divided into three activities, each involving all the partners (figure 1).

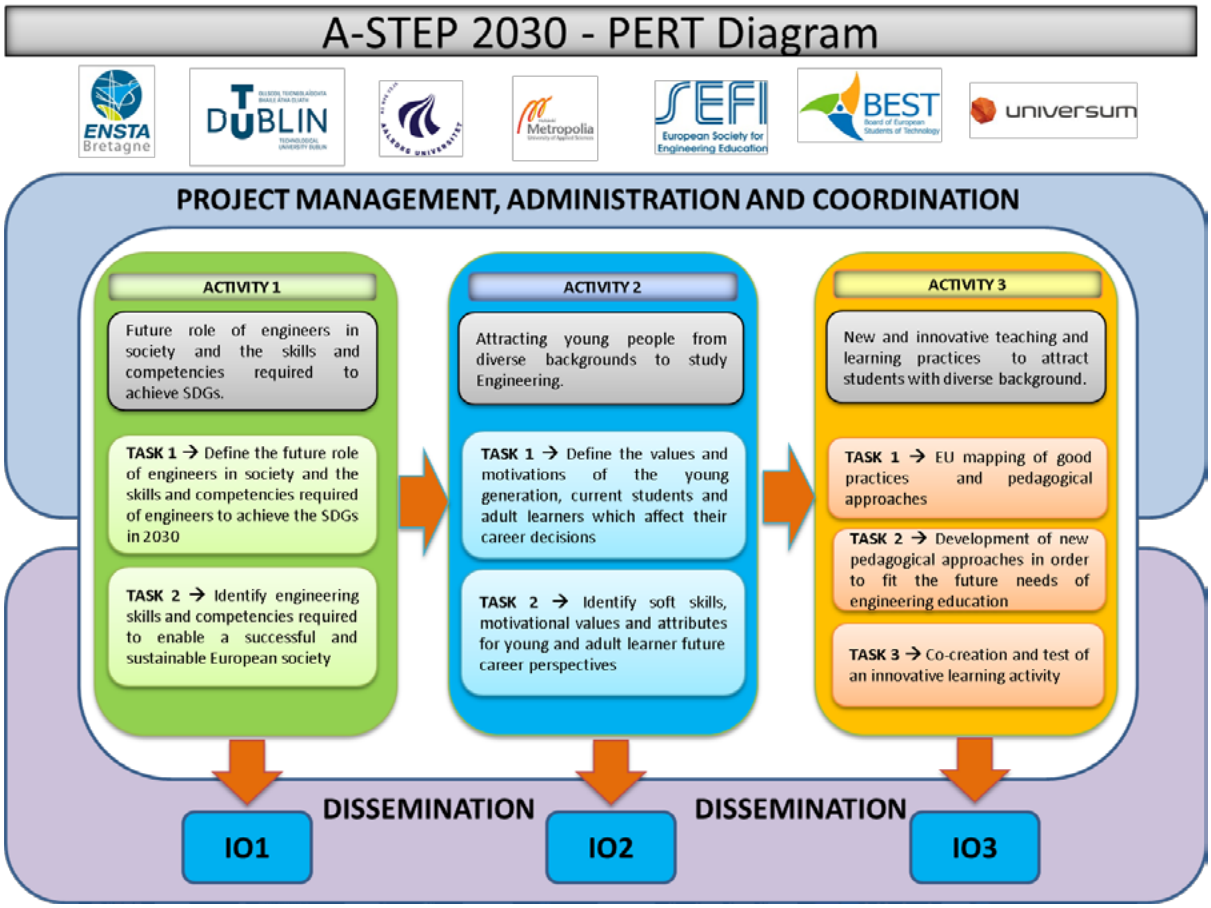

Fig. 1. The project plan showing the three key activities and the tasks within them, leading to dissemination outputs. All activities involved all partners to greater or lesser degrees

Additionally to the project partners, the plan included several advisers. The role of the advisers has been to view the plans, expected outcomes, methods, success of dissemination and especially to ask questions. This paper is written collaboratively by two advisers, representing important stakeholders, and having actively participated to the flow of the project together with the leader of the activity 2.

2.2 Metodology of activity 2

EU mapping of future engineering work, in the context of the values held by engineering students of today, was undertaken by a Universum study. The questions relating to this mapping were selected by all the project participants. These were:

1. Which of these career goals are most important to you?
2. How would you rate yourself in the following skills?
3. Which of these employer attributes are most important to you?

For each question, the differences between male and female engineering students, engineering and humanities students and students from generations Y (born between 1980 - 1995, age 23 - 38) and Z (born 1996 - 2001, age 17 - 22) were investigated in six target countries. These results were analysed in each of the countries and the differences/similarities between the countries compared.
Furthermore the Board of European Students of Technology organised two symposia with results that provide guidance to universities and other stakeholders as to what they can do in order to improve the diversity. Finally, in activity 2 an online survey to high school pupils with an approximate age of 16, was made to collect information about their values, interests, and expectations related to the Sustainable Development Goals (SDGs) and to their future. The leader of the activity 2 had the responsibility to assemble these results and create the intellectual output 2.

3 RESULTS

3.1 Outcomes from activity 2

From figure 2 it can be seen that students' career goals are quite similar. The biggest difference is in the goal "To be dedicated to a cause or serve a greated good", in which humanities and female engineering students had a much greater appreciation of this goal than male engineering students. The same difference can be seen in the goal "To be a technical or functional expert", in which male engineering students were more enthusiastic on these issues than female engineering students and much more than humanities students. "To have a work/life balance" was the highest valued career goal within all student groups. At the same time as the students valued a strong good work/life balance, they stated that their weakest soft skill was "Time management". The other weak soft skill for all students was "Integrity". In "Communication" skills there still seems to be room for development with all students, even though humanities students trusted themselves more regarding this skill than did engineering students. Engineering students thought that their strongest soft skills were: "Problem-solving", "Responsibility" and "Teamwork", while humanities student considered their strongest soft skills to be: "Responsibility", "Positive attitude" and "Adaptability". In "Responsibility", the younger generation Z appeared to make a somewhat better showing than the older Generation Y. [5]

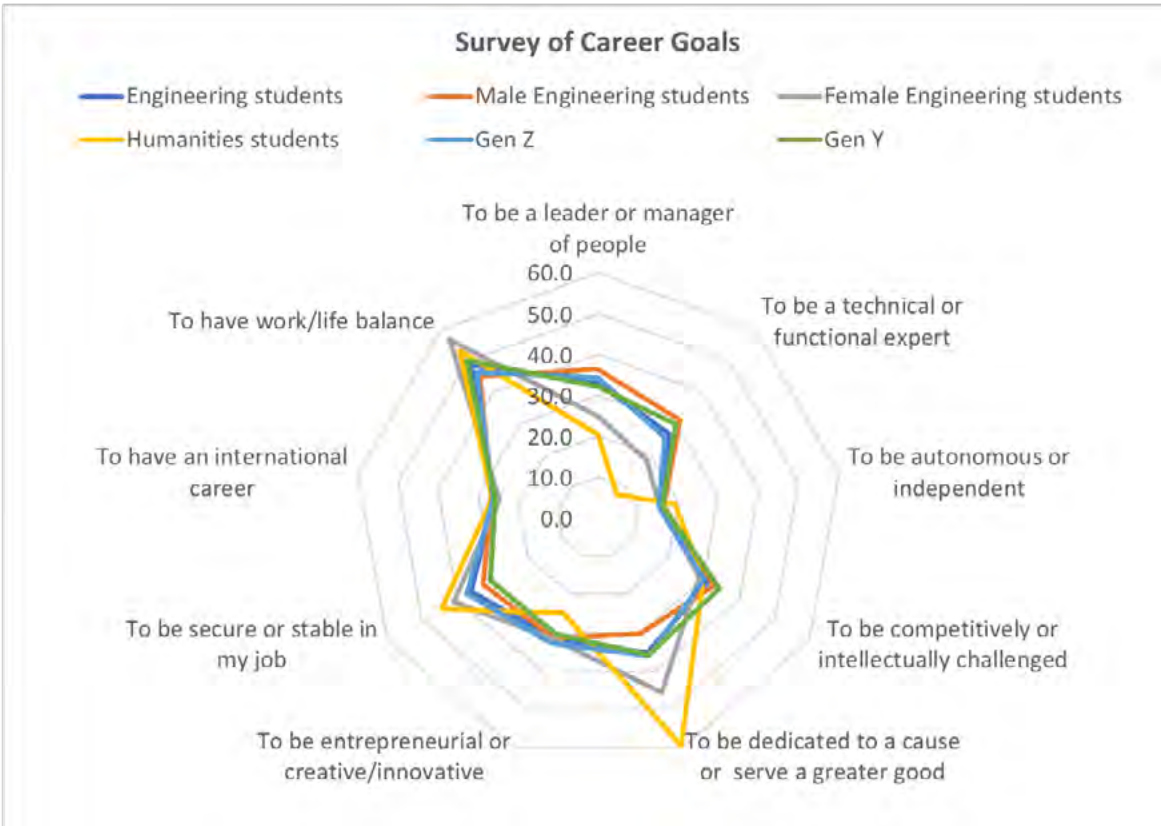

Fig. 2. Result of survey of career goals of averages of six groups, namely: engineering students, male engineering students, female engineering students, humanities students, generation Z (at current age of 17-22 years) and generation Y (at current age 23-38). The figures are shown as percentages of how many of the replies set that goal amongst the 3 most important.

It can be said that there is a general tendency among students in all countries now to accord more importance to issues surrounding environmental and social responsibility when compared to economic issues, which was certainly not the case in the past. Both humanities students and female engineering students place a particularly elevated value on these environmental and social responsibility issues, rating them highly regarded in both their career goals and employer expectations. For example, all humanities students considered the career goal “To be dedicated to a cause or to feel that I am serving a greater good”, and having “inspiring purpose” to be the most important.

A largest difference between engineering and humanities students can be seen in their expectations of their future employers. From figure 3 it can be seen that employer attributes “Inspiring purpose”, “Ethical standards”, “Corporate social responsibility” and “Commitment to diversity and inclusion” were much more important attributes to humanities students than to engineering students. With both humanities students and also female engineering students raising “Gender equality” into very important work attribute, which was not the case for male engineering students.[5]

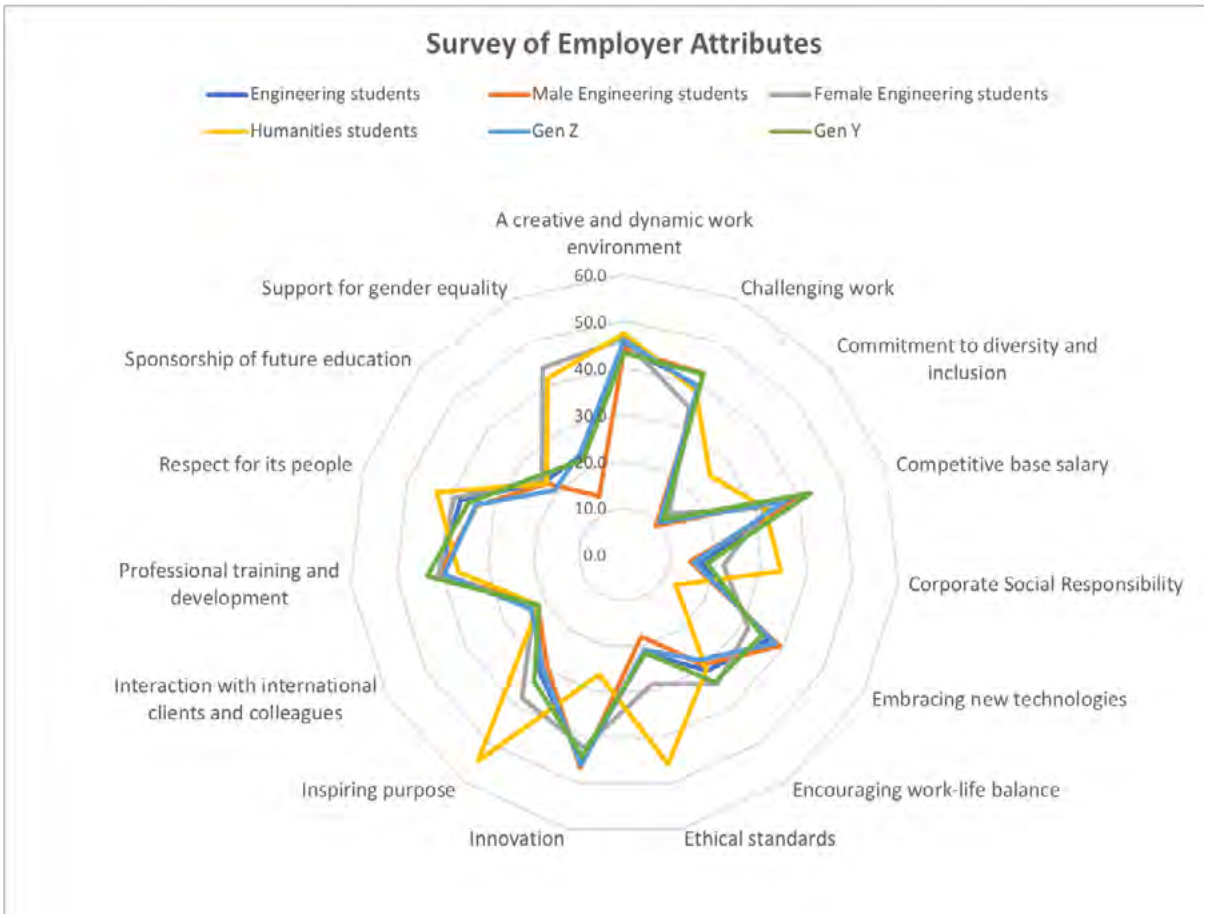

Fig. 3. Result of a survey of attractive employer attributes of the same six groups, namely: engineering students, male engineering students, female engineering students, humanities students, generation Z (at current age of 17-22 years) and generation Y (at current age 23-38). The figures show percentages of how many of the replies set that goal amongst the 3 most important.

The results of the on-line-survey for 16-year-old students' correlates with the findings of the Universum study (EU mapping of future engineering work in connection with the values held by engineering students of today). The pupils demonstrated a high degree of awareness of SDGs and were much more willing to promote sustainable development. The most important SDG for them was "Good Health and Well-Being". Also, more than 60% of pupils had selected "Quality Education", "Zero Hunger" and "Climate Action" among the three most important SDGs. According to their answers, most of the pupils were willing to work in groups, ready to apply technology, and prepared to solve challenging problems in multicultural environments.[5]

3.2 Conclusions

To address the students' wish to have a good work/life balance attention during their education will need to be given to improve their time management skills, which they identified as their weakest soft skill. Engineering students' strongest soft skills "Problem solving", "Responsibility" and "Team work" form a very good basis for solving big, global environmental, social and economical problems. The results could be even

better if humanities students' highly valued employer attributes of "Inspiring purpose", "Ethical standards", "Corporate social responsibility", "Gender equality" and "Commitment to diversity and inclusion" could be combined with these.

Comparing the outcomes of the activity 1 about the required competences for the future to respond effectively to the UN SDGs the conclusion was reached that there is no conflict in the preferences of the students, both in engineering and humanities as well as 16-year-olds. These results are in strong agreement with the results of a recent study completed by Finnish researchers [6]. The majority in all the groups studied expressed the desire to have a purposeful job and the feeling of serving a greater good. Competences for such jobs are very much based on those of engineering. These different results are convincing in showing that engineering education and solutions need to be "marketed" in a clear way to show they are essential for future sustainable development of the globe. Still too often, engineering and technology subjects have to face the reputation for being difficult and leading inevitably to more pollution and other problems.

To improve the reputation and reach a more diverse source of potential students to apply for engineering studies, the STEM subjects need changes in the nature of their education. The focus of the education should be less in teaching and more in learning in a way that the issues have a more direct connection to the understanding of the challenges of the future. While the content of the STEM studies might remain much as it is currently, the pedagogical methods need to be developed in a way that the non-technical competences will be developed simultaneously. By using more real life examples or case studies, experimental methods, project and problem based learning and working in teams, the variety of skills and competences could developed more effectively and concurrently than it is today. As part of this it is important that all the necessary competences are measured and thus made more visible in the evaluation process of students.

4 SUMMARY

The results of the activity 2 are strenghening the vision of a need for flexible learning methods and a stronger connection to working life. Attractive projects, where diverse students are solving real problems together in a well guided process, would in addition to the development of technological competences, lead to an enhancement of competences. These might be to manage time, work-life balance, communication and an understanding of environmental, social and economical circumstances in life cycles of products and services for human use. This should form a strong starting point for activity 3 led by Aalborg University an institution which has a reputation for its pioneering application of the Problem-based Learning (PBL) approach.

5 ACKNOWLEDGMENTS

We would like to acknowledge the EU Erasmus+ funding body and all partners and associated partners in the A-STEP 2030 project for their help in Activity 2.

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EDUCATION FOR SUSTAINABLE DEVELOPMENT GOALS IN SPANISH ENGINEERING DEGREES

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ABSTRACT

EDINSOST and EDINSOST2 are two Spanish R&D+I funded projects. Their objective is to facilitate the training of graduates to be capable of leading the resolution of challenges in our society through the integration of sustainability training in the Spanish University System. Both projects focus, among other degrees, in engineering degrees. EDINSOST is organized around four specific objectives:
1) To define the Sustainability Competency Map of each engineering degree and establish a framework for incorporating the map into the degree curricula;
2) To validate didactic strategies for addressing sustainability from a constructivist and community pedagogical approach;
3) To diagnose the status of the sustainability training needs of faculty and develop and test training proposals
4) To diagnose the sustainability competency level of students and validate training proposals.
EDINSOST2 advances from developing sustainability competencies to develop SDGs learning objectives. It is currently in its early stages, so the results are preliminary. Although the data collection stage is over, the analysis of the collected data is still underway. This paper presents the main results of the EDINSOST project in the field of engineering education, and some preliminary results of EDINSOST2. In relation to the first EDINSOST objective, a sustainability competency map has been defined. Based on this map, the most appropriate didactic strategies for sustainability training have been analyzed and tested, and the state of the sustainability training requirements in teachers and students have been diagnosed. Proposals for training both groups will be developed in EDINSOST2.

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1. INTRODUCTION

1.1. Motivation

Contemporary society faces global challenges such as the economic crisis, climate change, desertification, deforestation, inequalities, wars and the eradication of poverty. In this global context, the promotion of Sustainable Development has gained broad international recognition as the way forward to ensure quality of life, equity between present and future generations and environmental health [1, 2]. Although the conceptualization of Sustainable Development remains controversial, a global consensus exists about the need to raise awareness and develop strategies and action plans to address the global challenges facing society today [1]. These changes are represented by the United Nations Agenda 2030 [3] and the Sustainable Development Goals (SDGs) approved by UNESCO [4] with the aim of being achieved in the year 2030. Achieving these objectives implies the need to establish action frameworks that facilitate an education for the participation, awareness and training of citizens.

The integration of Education for Sustainable Development (ESD) into Higher Education to achieve SDGs contributes to the development of university graduates' skills related to sustainability, such as critical and creative thinking, problem solving, capability to act, collaborative competence and systemic thinking. This development will allow us to form potential agents of change, capable of shaping a more sustainable society.

In the past decade, much insight has been gained into the task that lies ahead. With hindsight, one might say that the approaches taken to institute sustainability in engineering education in the 1990s were somewhat naïve: Developing an add-on course, teaching other teachers about Sustainable Development and creating a track for Sustainable Development specialists are at best just the first step. The next steps to be taken in ESD should not only concern which course should be added to make engineering more sustainable in an always "crowded" curriculum, but also addressing the question of what type of curriculum might contribute effectively to Sustainable Development so that SDGs could be reached in 2030. Instead of adapting an unsustainable curriculum or introducing Sustainable Development, curricula should be rebuilt by benefitting from ESD expertise as the leading principle for curricula. This will not happen if faculty members are not equipped for the task. Dealing with Sustainable Development and social models helps faculty propose actions for improving the methodology and thereby enhance students' competencies [5]. The full integration of Sustainable Development into a subject requires both sustainability content as well as suitable learning strategies. A focus on how we teach as much as what we teach is important, if we are to educate for Sustainable Development. Moreover, active learning strategies are necessary for creating the integrated and inter- and trans-disciplinary perspective required for sustainability education [6]. A set of guiding principles for the design of innovative active learning experiences may be drawn from the results of the Experiencing i-Design project described in Secundo et al. [7].

1.2. The EDINSOST projects

In order to achieve a better training of future engineers in terms of ESD, the EDINSOST project [8] started working in Spain in 2016 with four objectives:

- Objective 1 (O1): To define Sustainability Competency Maps for each of the participating degrees and establish a framework for incorporating the maps into the degrees in a holistic way;
- Objective 2 (O2): To validate different didactic strategies for addressing sustainability through a constructivist and community pedagogical approach;
- Objective 3 (O3): To diagnose the status of the training needs of each degree's teachers with regard to sustainability, as well as to develop and test training proposals;
- Objective 4 (O4): To diagnose the sustainability competency level of current university students and to develop and test training proposals.

The EDINSOST project ended in 2019. That same year, the EDISNSOT2 project began. Society needs SDGs to be introduced into university curricula so that these can be achieved successfully in 2030. This is the main goal of EDINSOST2. EDINSOST was an analysis project. EDINSOST2 is an intervention project. Its objective is to influence the design of various degrees and to analyze the results obtained at the end of the four-year duration of the project. EDINSOST2 has practically just started, so this paper only presents preliminary results related to one of its objectives: Identifying the SDGs in the EDINSOST' sustainability competency maps.

Due to space limitations, this paper focuses solely on engineering degrees, despite the fact that EDINSOST projects have also developed tools for university degrees related to education and business.

2. METHODOLOGY

2.1. EDINSOST Objective O1

EDINSOST's objective 1 is to develop Sustainability Maps for the degrees analyzed in the project. These maps characterize the sustainability competencies that students have to master to carry out their professional activity according to the principles of sustainable development. These maps have been designed on the basis of the four competencies related to sustainability defined by the Sectorial Commission CRUE-Sustainability [9]:

- C1: Critical contextualization of knowledge by establishing interrelations with social, economic, environmental, local and/or global problems.
- C2: Sustainable use of resources and prevention of negative impacts on the natural and social environment.
- C3: Participation in community processes that promote sustainability.
- C4: Application of ethical principles related to the values of sustainability in personal and professional behavior.

Each Sustainability Map contains a set of learning outcomes organized in a matrix. Rows contain competency units classified according to the three dimensions of

sustainability (social, environmental and economic) and the four CRUE sustainability competencies, while columns indicate the domain level of the learning outcomes according to a given taxonomy. The taxonomy used by EDINSOST is a simplified version of the Miller's pyramid [10]. This taxonomy has three levels only: L1-Know, L2: Know-how and L3: Demonstrate + Do (the two upper levels of the Miller's pyramid, demonstrate + do, have been integrated into a single level). The sustainability maps developed in EDINSOST for the different degrees involved in the study can be found in Sanchez-Carracedo et al. [11,12]. Table 1 shows the definition scheme of a sustainability competency in a Sustainability Map.

Table 1. Scheme of a sustainability competency in a Sustainability Map

Competency	Dimension	Competency Units	Domain levels		
			Know	Know how	Demonstrate+do
C1..C4	Holistic	CUs	LOs	LOs	LOs
	Environmental	CUs	LOs	LOs	LOs
	Social	CUs	LOs	LOs	LOs
	Economical	CUs	LOs	LOs	LOs

Each competency is addressed in the four dimensions indicated in Table 1, but in general, efforts have been made to work solely with the holistic dimension. Each dimension is defined by one or more Competency Units (CUs). Each CU's domain level defines one or more Learning Outcome (LOs). In order to achieve the simplest possible Sustainability Map, we have tried to minimize both the number of CUs and LOs.

2.2. Objective O2

Pedagogical approaches used in our previous research were evaluated in order to validate the most effective didactic strategies [13]. Previous results showed that the more effective pedagogy for sustainability learning were those that are community oriented and apply constructive learning schemes. Taking this into account, we selected five teaching strategies in the EDINSOST project: Problem-Based Learning; Project-Oriented Learning; Service learning; Simulation; and Case Studies [14].
To evaluate their effectiveness, we analyzed 2 case studies of each pedagogical approaches and measured students' learning through pre and post questionnaires. The questionnaires used were those defined for objective O4 below.

2.3. Objectives O3 and O4

To achieve objectives O3 and O4, several questionnaires have been designed adapted to both teachers and students. The questionnaires have been designed according to the learning outcomes defined in the Sustainability Maps. All the

questionnaires have passed a validation process. The validation has been carried out by a group of experts and by a students' control group. Both groups have evaluated the relevance and clarity of the questions. An example of questionnaire for ICT students can be found in [15].
The questionnaire for engineering students consisted of 34 questions. The engineering faculty questionnaire integrates the questions corresponding to objectives O2 and O3, and consists of 62 questions.

2.4. EDINSOST 2

The Sustainability Maps developed in EDINSOST for the different degrees involved in the study [11,15] are the starting point for developing the objective O1 of the EDINSOST2 project. EDINSOST2 aims at introducing the SDGs in university degrees by aligning them with the learning outcomes identified in the Sustainability Maps.
UNESCO [4] defined each of the 17 SDGs in the form of 15 learning objectives: 5 cognitive objectives, 5 socio-emotional objectives and 5 behavioral objectives. Together, a total of 255 learning objectives were defined.
To achieve the objective O1 of EDINSOST 2, a matrix has been constructed which relates the 255 learning objectives defined by UNESCO [4] with the learning outcomes of the Sustainability Maps. In the case of engineering degrees, we discern when the Learning Objective of a certain SDG should be developed in all engineering degrees or only in some particular engineering degree.

3. RESULTS

3.1. EDINSOST Objective 1

Based on the learning outcomes defined in the Engineering Sustainability Map, the learning guides of all the subjects corresponding to the following six engineering degrees from three universities have been analyzed:

- Bachelor Degree in Electrical Engineering (BDEE) at the University of Córdoba (UCO) and Universitat Politècnica de Catalunya – BarcelonaTech (UPC).
- Bachelor Degree in Informatics Engineering (BDIE) at the UCO, UPC, and Universidad Politécnica de Madrid (UPM).
- Bachelor Degree in Mechanical Engineering (BDME) at the UCO and UPC.
- Bachelor Degree in Design Engineering (BDDE) at UPC.
- Bachelor Degree in Chemical Engineering (BDCHE) at UPM.
- Bachelor Degree in Industrial-Technologies Engineering (BDITE) at the UPM.

Figure 1 shows the presence of each sustainability competency defined by the CRUE in each of the degrees.

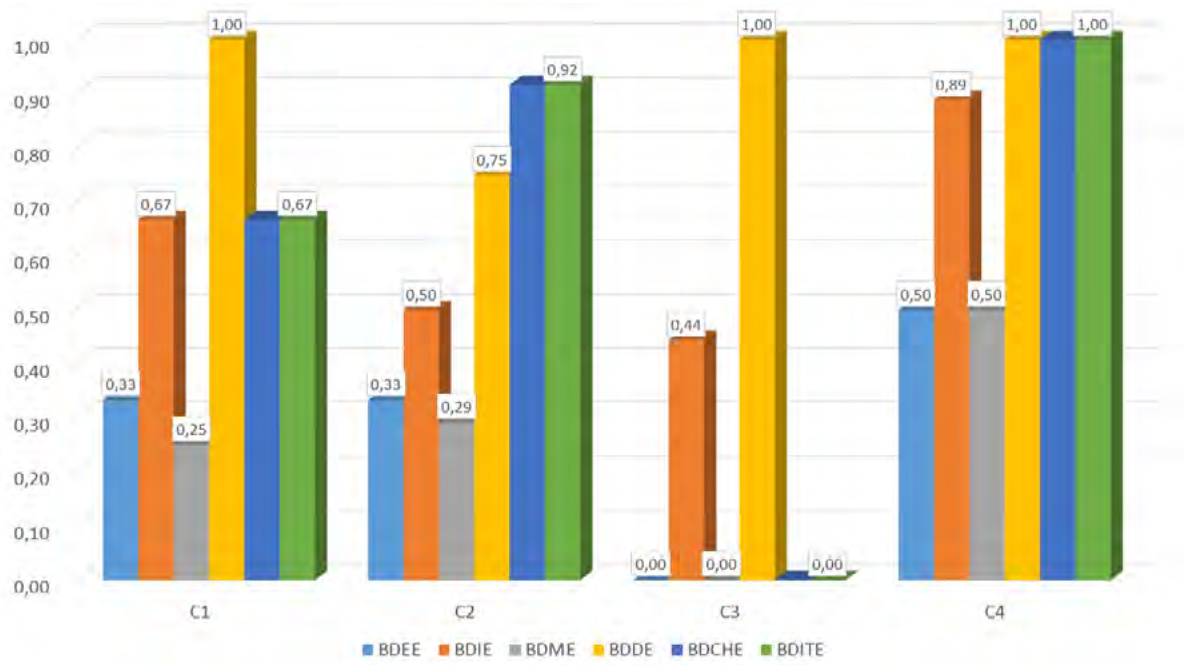

Fig. 1. Presence of each CRUE sustainability competency in each engineering degree.

Figure 1 shows that no competency pattern can be discerned as no competency has the same level of presence for all degrees. However, C3 (Participation in community processes) is absent in 4 of the 6 degrees analyzed. On the other hand, C4 (Application of ethical principles) has a 100% presence in three degrees, and C2 (Sustainable use of resources) has a 92% presence in two degrees.
A comprehensive analysis of the presence of sustainability competencies in this set of engineering degrees can be found in [12]

3.2. EDINSOST Objective 2

The results are the definition of a methodology of didactic strategies for university education in sustainability and a table for each didactic strategy in which the guidelines for its correct application are indicated. To illustrate these results, Table 2 shows an example of the methodology employed for the Service-Learning strategy.

Table 2: Methodology of didactic strategies for university education in sustainability. Example for Service Learning

Justification	It engages students in learning through a service to the community with a focus on justice and social and/or environmental responsibility, which produces a reciprocal benefit.
Challenge for students	Engage students in the service to improve understanding of academic concepts through practical learning, as an instrument of social and political reform that promotes sustainable development and social justice.
Work Modality	Basically active, participatory, and reflective through collaboration in a project, with some individual tasks.
Teacher's role	Tutor, facilitator
1. Preparation Phase	1.1. Idea outline
	1.2. Relationship with entities
	1.3. Project planning
2. Execution Phase	2.1. Perform the service
	2.2. Relate to the people and entities in the environment
	2.3. Register, communicate and disseminate the project
	2.4. Reflect on the learning of execution
3. Evaluation Phase	3.1. Joint evaluation

3.3. EDINSOST Objective 3

The questionnaire was applied to all the teachers involved in the degrees under study and in all the consortium universities where these degrees are offered. In engineering degrees, the questionnaire was applied to the University of Córdoba (teaching population: 211; sample: 26; participation: 12%), Universidad Politécnica de Madrid (teaching population: 2919; sample: 182; participation: 6%), and Universitat Politècnica de Catalunya-BarcelonaTech (teaching population: 3056; sample: 322; participation: 11%), which amounts to a total teaching population of 5,196, a sample of 530 questionnaires and a participation rate of 9%.
The questionnaire used a four-point Likert scale (totally disagree, strongly disagree, strongly agree and totally agree) to the statements concerning each of the competencies and Competency Units, and assesses the three domain levels of the Engineering Sustainability Map.

Results show that the majority of respondents (63%) agree with the statements; therefore, competencies have been acquired to some extent. However, 37% of respondents still disagree with the statements, so there is a clear need for training for that sample. The analysis by competencies shows (see Figure 2) that competency C1 (Critical contextualization of knowledge when establishing interrelations with social, economic, environmental, local and/or global problems) has been acquired to the greatest extent (71% agreement). The analysis also shows that competency C2 (Sustainable use of resources and prevention of negative impacts on the natural and social environment), with a 38% disagreement, has been the least acquired [8].

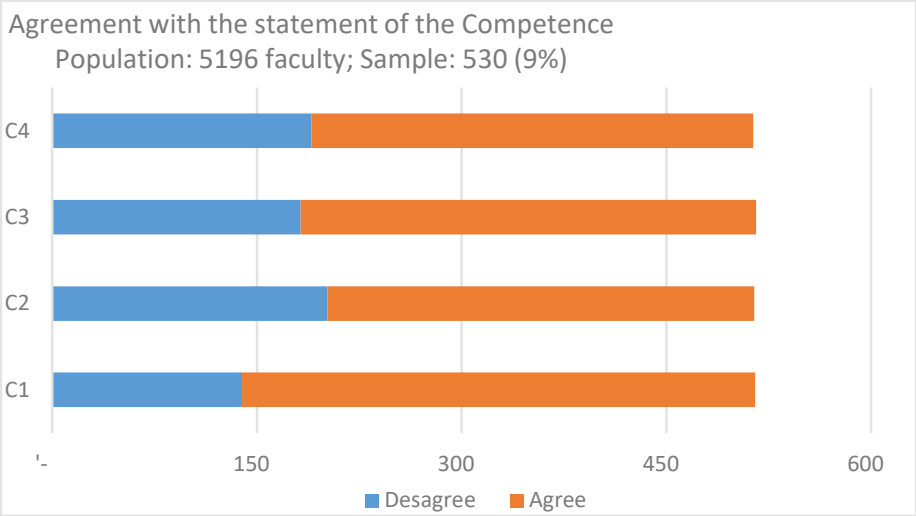

Fig. 2. Results of the evaluation of the four sustainability competencies for engineering degrees.

3.4. EDINSOST Objective 4

Objective O4 of the EDINSOST project tries to answer the question: How much do engineering students in the Spanish university system improve their sustainability skills during their studies at the university?

To achieve this objective, first and fourth year students from four degrees from three universities have been surveyed:

- Bachelor Degree in Informatics Engineering from the Universidad Politècnica de Catalunya - BarcelonaTech (UPC), the Universidad Politécnica de Madrid (UPM) and the University of Seville (US).
- Bachelor Degree in Mechanics Engineering from UPC and US
- Bachelor Degree in Chemical Engineering from UPM and US
- Bachelor Degree in Industrial Technologies Engineering from UPM and US

There have been 1157 responses from first-year students and 525 responses from fourth-year students who are taking their Bachelor Thesis. Results are shown in Figure 3.

Figure 3 shows the perception of engineering students about their competence in the four sustainability competencies. The gray bars correspond to first-year students,

while the white bars show the improvement in skills perceived by fourth-year students.

The questionnaire responses were on a 4-point Likert scale, and were translated numerically on a 0 to 3 scale. Figure 3 shows that first-year students consider that they are approximately 50% proficient in the four competencies at the beginning of their studies. Fourth year students consider themselves a little more competent, but they barely achieve 66% of the result they should achieve (two out of three). Competency C4 (ethical principles) is the one in which students state that they feel the least capable at, both in first and fourth grade, while competency C3 (collaborative work) is the one in which they declare themselves most capable. These data contradict those shown in Figure 1, which seems to indicate that the learning guides of the subjects do not reflect what the students really learn, or that the students are trained in sustainability outside the university.

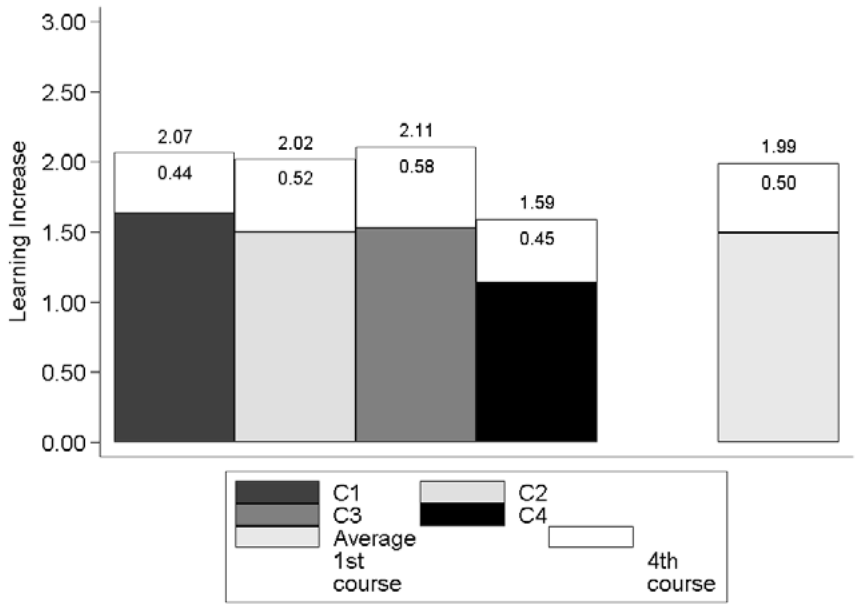

Fig. 3. Perception of first and fourth year students of engineering degrees about their learning in the four sustainability competencies

3.5. EDINSOST 2 Objective 1

Once the EDINSOST Engineering Sustainability Map has been defined, the first aim of the objective O1 of EDISNSOST2 project is to see how SDGs are present in the Sustainability Map. To do so, we analyzed whether the 255 SDG learning objectives corresponded to any of the learning outcomes on the map. Table 3 shows these results.

Table 3. Learning objectives of each SDG that must be developed in an engineering degree

	SDG																
Learning Objectives	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
C1	No Eng	No Eng	ENG	No Eng	No Eng	No Eng	ENG	ENG	ENG	ENG	ENG	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng
C2	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	No Eng	ENG	ENG	ENG	ENG	No Eng	No Eng	No Eng	No Eng	ENG
C3	ENG	No Eng	No Eng	ENG	No Eng	ENG	ENG	No Eng	ENG	No Eng	ENG	ENG	ENG	No Eng	ENG	No Eng	No Eng
C4	ENG	ENG	No Eng	ENG	No Eng	ENG	ENG	No Eng	ENG	ENG	ENG	ENG	ENG	No Eng	ENG	ENG	ENG
C5	No Eng	ENG	No Eng	ENG	ENG	ENG	No Eng	No Eng	ENG	No Eng	ENG	ENG	ENG	No Eng	ENG	ENG	ENG
S1	No Eng	ENG	No Eng	No Eng	No Eng	ENG	ENG	No Eng	No Eng	ENG	ENG	No Eng	ENG	No Eng	No Eng	No Eng	No Eng
S2	No Eng	ENG	No Eng	No Eng	No Eng	ENG	ENG	No Eng	No Eng	No Eng	ENG	ENG	No Eng	No Eng	No Eng	No Eng	No Eng
S3	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	No Eng	No Eng	No Eng	ENG
S4	No Eng	ENG	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	No Eng
S5	ENG	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	No Eng	No Eng	ENG	No Eng	ENG	No Eng	No Eng	No Eng	No Eng	No Eng
B1	ENG	ENG	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	ENG	ENG	ENG	ENG	ENG	No Eng	No Eng	No Eng	ENG
B2	No Eng	ENG	No Eng	No Eng	ENG	No Eng	ENG	No Eng	ENG	ENG	ENG	No Eng	No Eng	No Eng	ENG	No Eng	No Eng
B3	No Eng	ENG	No Eng	No Eng	No Eng	No Eng	ENG	ENG	ENG	ENG	No Eng	ENG	ENG	No Eng	No Eng	No Eng	No Eng
B4	No Eng	No Eng	No Eng	No Eng	No Eng	ENG	No Eng	ENG	No Eng	ENG	ENG	ENG	ENG	No Eng	ENG	No Eng	No Eng
B5	ENG	ENG	No Eng	No Eng	No Eng	No Eng	ENG	ENG	ENG	No Eng	ENG	No Eng	ENG	No Eng	No Eng	No Eng	ENG

Table 3's rows show the learning objectives as they have been classified by UNESCO, numbered in order of appearance in the document [4]: Cognitive (C), Socio-emotional (S) and behavioral (B). The learning objectives highlighted in green and labeled as ENG correspond to the objectives that must be developed in some engineering degree. The learning objectives highlighted in red correspond to the objectives that must be developed in degrees of any educational level that are not related to engineering.

As can be seen in the table, there are SDGs very related to engineering (such as SDG 11-sustainable cities) and others that have little or no relationship (such as SDG 14-Life water).

4. CONCLUSIONS

This paper presents the results of the EDINSOST project and preliminary results of the EDISNSOT2 project. The projects encampases 13 degrees in 10 Spanish universities, in the fields of education, engineering and sustainability.

The EDINSOST project had four objectives: (O1) to build the sustainability map of the degrees under analysis; (O2) to validate didactic strategies for learning sustainability; (O3) to diagnose the status of the sustainability training needs of teachers, and (O4) to diagnose the status of the sustainability training needs of students. The first objective has been completed successfully. Given the transversal nature of sustainability, four Sustainability Maps have been drawn up to address sustainability in all the degrees. The project analyzed how the different degrees fit their respective Sustainability Maps. In Objective O2, five teaching strategies were selected and analyzed: Problem-Based Learning; Project-Oriented Learning; Service Learning; Simulation; and Case Studies. For each didactic strategy, the project analyzed how it can contribute to learning sustainability and how it should be used to achieve this objective. To achieve Objectives O3 and O4, several questionnaires were designed, submitted to and answered by 858 teachers and 3,766 students. The questionnaires were validated beforehand and adapted to each degree. This data is currently being analyzed. Several discussion groups were also organized with both teachers and

students in order to conduct both a qualitative and a quantitative analysis from the answers to the questionnaires. Results reveal that there is a great disparity in the way in which sustainability is developed in the different Spanish university degrees. While some degrees include almost all subjects in developing sustainability, other degrees include only a few of them. Some degrees develop sustainability in elective subjects, while others also include it in compulsory subjects. It appears that teacher motivation plays a very important role, and sustainability is developed to a greater extent in those degrees taught by more motivated teachers. This fact implies that, with few exceptions, no guidelines are given in this regard from school management teams, and teachers are the one who finally decide, *motu proprio*, whether or not to develop sustainability in their subjects. Students perceive that sustainability is not developed properly in their respective degrees, a failing that is also due to their own self-assessed lack of knowledge about sustainability.
Results of EDINSOST2 project show that the Engineering Sustainability Map covers most of the 255 Learning objectives of the Agenda 2030 SDGs.

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PARALLEL DISCIPLINES: EXPLORING THE RELATIONSHIP BETWEEN GLOBAL AND ETHICS LEARNING OF UNDERGRADUATE ENGINEERING STUDENTS

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ABSTRACT

As globalization of technological systems proceeds and design problems become increasingly complex, preparing future engineers for this rapidly changing world is a top priority. Both accreditation boards and disciplinary organizations alike have recognized the importance of global and ethics educations as a core component of the engineering curriculum. While often thought of as largely different disciplines of knowledge, universities across the country are placing more of an emphasis on these two disciplines, some going as far as to incorporate them across the entire general education curriculum. This study seeks to shed light on the connections that global and ethics education may have. To study this correlation, this pilot study utilized the Global Perspective Inventory, a validated, web-based assessment that measures global learning across the cognitive, interpersonal, and intrapersonal dimensions. To parallel the Global Perspective Inventory, we constructed various survey items that paralleled the survey items, but with a focus on ethical identity and awareness. We distributed the modified survey to undergraduate engineering students at Virginia Tech. Through the use of paired t-tests, preliminary analysis of a small pilot group indicates a strong correlation across 8 of the 19 survey item pairs. More findings will be shared in the final draft. As we continue to further our understanding of both global and ethics educations in the engineering curriculum, we hope to increase the sample size of our study and incorporate various demographic factors to improve our understanding of global and ethics education.

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1 INTRODUCTION

Both ethical and global competencies have been highlighted as vital components of the engineering education curriculum. In the most recent accreditation criteria, ABET (the Accreditation Board for Engineering and Technology) stresses the importance of recognizing ethical responsibilities and considering their impact in both a global and societal context [1]. Similarly, the National Academy of Engineering (NAE) has outlined a need for engineering graduates to be prepared to address ethical considerations of engineering problems while working in multicultural and global teams [2]. As national and disciplinary organizations place more of an emphasis on ethical and global competencies for graduating engineering students, many engineering universities, departments, and faculty are doing the same.

While ethics and global education are often conceptualized differently, many similarities exist between the two competencies. Pedagogies used in engineering course work, such as case studies and role play, offers a platform for combining ethics and global education. Dempsey, Stamets, and Eggleson (2016) designed a role play scenario in which students practiced the skills of perspective-taking and empathy, each of which are components of moral development but also benefit a global engineer [3]. Sustainability is another area in which global and ethics education overlap. In examining the trends of sustainability in engineering education, Tejedor et al. (2018) found that words such as transdisciplinary, ethics, and networking all were increasing in sustainability education [4]. Shedding light on the relationship between ethical and global competencies is needed to identify how these two competencies can be included in a curriculum that will develop more holistic engineers.

2 BACKGROUND

2.1 Ethics Education

Ethics education has often been broken down into two general fields of study, microethics and macroethics. Microethics is concerned with issues at the individual level, such as responsible conduct of research (RCR) and conflicts of interest. Macroethics looks at the bigger picture, which can include discussions of sustainability and privacy [5], [6]. While microethics are more commonly taught in undergraduate engineering courses and may help students avoid certain pitfalls, macroethics helps students look at ethical dilemmas from a bigger picture, providing them with a more comprehensive view of the situation [7].
Ethics education is most commonly delivered in the classroom through case studies, which are either short stories of fictional or historical events, often revolving around the decision-making of an organization or individual. Students then respond to questions, individually, in groups, or as a class, to discuss the nuances of the ethical dilemma the agents in the stories faced [7]–[9]. An objective of this pedagogy is to have students think through realistic problems and come to a plan of action through collaborative perspective taking. Roleplaying and games are among the other pedagogies commonly employed by ethics education faculty across disciplines. Games similar to those described in Sadowski et al. are designed to engage students with ethical quandaries through the lens of reason rather than rules [10]. Role play, similar to case studies, allows students to examine a moral dilemma from

another's perspective [11]. However, by roleplaying as another individual, students may take on a self-oriented approach as opposed to an other-oriented approach [12]. By taking on a self-oriented approach, students can imagine how they would act or feel if they were the person in the story, as opposed to simply imagining how that person might feel [13].

2.2 Global Education

In the context of this paper, global education refers to education specifically designed to prepare students to navigate a globalized and culturally diverse world more effectively. Prompted by this idea of a global marketplace, one component of engineering education that has become prominent is designing for international communities and working in interdisciplinary and multinational teams [14], [15]. The impetus for global education in the design context is that it promotes both creativity and open-mindedness [16]. Students must be prepared to work in international settings with international goals in the foreseeable future [17].

Study abroad programs offer unique opportunities for some engineering students to develop global competencies. By visiting another country or culture for anywhere from a week to a summer, students have the opportunity to learn about and be immersed in a different culture. By providing avenues for students to experience other cultures, students might expand their worldview, and in doing so learn the value of working with individuals from different backgrounds from themselves. Similarly, opportunities such as Engineering without Borders and the Semester at Sea also provide globally-oriented experiences to engineering students [18]. Another approach that allows students to engage with global competencies is through projects with international and multicultural partners, such as where these might replace or act as extensions to current capstone and design projects [17]. However, some authors have noted that such programs, whether inter- or intra-cultural, require significant contextual preparation to avoid counterproductive outcomes, with disparities in social capital among participants being an especially conspicuous obstacle [19]. Part of this preparation involves development of cognitive and social skills, which may be applicable in both intercultural and ethical domains. Examining the overlap between these domains in the context of undergraduate engineering education is our primary focus here.

2.3 Parallels and the Global Perspective Inventory

The Global Perspective Inventory (GPI) is a validated survey instrument developed at Iowa State University that examines the cognitive, intrapersonal, and interpersonal dimensions of an individual's ability to take the perspectives of others into account. It is grounded in cultural development and intercultural communication theories. Cultural development theory outlines three domains, the cognitive, the intrapersonal, and the interpersonal through which students construct meaning and make sense of the world around them [20].

Intercultural communication theory emphasizes three important domains for success in communicating in intercultural contexts: the affective, the cognitive, and the

behavioral [20]. These three domains also appear in empathy literature, which has been operationalized in engineering ethics literature as the ethics of care [21]. In fact, empathy seems to be at the core of what connects the theoretical underpinnings of global and ethics education. Segal (2011) defines empathy as "the ability to understand people by perceiving or experiencing their life situations and as a result gain insight into structural inequalities and disparities" [22]. In the domain of engineering ethics, empathy allows engineers to incorporate the perspectives of stakeholders and customers into the decision-making process. As a parallel to this, in the domain of global engineering, empathy allows engineers to incorporate the perspectives of those with different cultural and national backgrounds. The GPI is a validated tool for measuring the perspective taking ability of students with different global contexts. With this connection of empathy in mind, we have adapted the GPI to also measure the perspective taking ability of students in the context of ethics as well.

3 METHODOLOGY

3.1 Research Aims

The goal of this research was to examine the parallels between ethics and global education through the use of the GPI survey. By creating questions that directly parallel the GPI with ethical counterparts, our aim is to understand how perspective taking in these two domains relate. We anticipate that our research will show how to conduct research and design pedagogies for improving the global and ethical competencies of our students. To accomplish these research aims, we sought to answer these specific questions:

RQ1. How do global and ethical perspective-taking relate to each other?

3.2 Settings and Participants

To answer this research question, we conducted a preliminary study at a large comprehensive, engineering focused, university in the US (Virginia Tech). At the time of data collection, the undergraduate engineering population was 6,000 students. Students were recruited from a plethora of senior capstone and first-year general education courses, across disciplines.

Students were informed of the study in one of their prior class sessions and provided the opportunity and time to complete the survey during class time, which took approximately 5 minutes. Faculty members were given the option to provide students with extra credit. Only those who provided consent (as granted during the first question of the survey), were included in the survey. This study was approved by the Virginia Tech's Institutional Review Board. The self-selected sample consisted of approximately 220 students.

3.3 Global Perspective Inventory

The survey instrument consisted of two portions, the Global Perspective Inventory (GPI) and the Ethical Perspective Inventory (EPI) extension. Both the GPI and the EPI utilize Likert-like responses ranging from 'Strongly Disagree' to 'Strongly Agree.' The GPI is divided into three domains, the cognitive, intrapersonal, and

interpersonal, each of which contains two subscales. The cognitive dimension pertains to thinking and is divided into the knowing and knowledge subscales. Knowing refers to the complexity of thinking about multicultural issues while knowledge refers to the knowledge the student has of multicultural issues. The intrapersonal dimension is divided into identity and affect. The former pertains to an individual's understanding and accepting of their personal sense of purpose while the latter refers to how much in individual respects and accepts the differences between them and others. The third domain is the interpersonal domain, which refers to how one interacts with others, and is divided into two subscales, the social responsibility scale and the social interaction scale. The social responsibility scale pertains to an individual having concern for others and the social interaction scale relates to the affinity one has for engaging with others who are from different backgrounds. The number of survey items pertaining to each subscale can be seen below in Table 1. The full list of survey items can be found below in Appendix A.

3.4 Ethical Perspective Index Extension

To create the corollary survey items for examining ethical perspectives of students, our research team first outlined which survey items we thought needed to be altered. The standard GPI instrument consists of 35 questions. Of these, 16 can be straightforwardly construed as probing ethical perspectives in their original form. For example, the statement "In different settings what is right and wrong is simple to determine" has obvious ethical implications, and can reasonably be applied in both global/intercultural situations and local/intracultural ones. In this sense, almost half of the standard GPI should already be considered a direct survey of ethical perspectives. The remaining 19 survey items in the GPI are, instead, specific to intercultural contexts, and were altered to create the EPI extension. The purpose of this extension is to provide a parallel set of questions that eliminate any references to cultural differences and replace those with value differences instead. As an example, "I intentionally involve people from many cultural backgrounds in my life" from the GPI was altered to "I intentionally involve people with different viewpoints in my life". This shift in wording re-contextualizes the question to focus on differences in attitude instead of differences in identity. Comparison of responses to this pair of questions can thus serve to probe the correlation between ethical and intercultural perspectives. Once the survey items to be altered had been decided upon, the team created multiple alternatives survey items for each corollary in the EPI and discussed each one at length, consulting experts outside of the research team to ensure that each survey item was appropriate and parallel to the GPI survey item. The breakdown of added questions can be seen across domains and subscales in Table 1. The full survey can be seen in Appendix A.

Table 1. Summary of Survey Items

Survey Section/Scale	Subscale	Items
Global Perspective Inventory (35 Items)	Cognitive Knowing (CogEp)	7
	Cognitive Knowledge (CogKnw)	5
	Identity (Ident)	6
	Affect (Affect)	5
	Social Responsibility (SocRes)	5
	Social Interactions (SocInt)	4
	Global Citizen (GloCit)	1
	Threat (Threat)	1
	Comfort (Comfor)	1
Ethical Perspective Inventory (19 Items)	Cognitive Knowing (EthCogEp)	5
	Cognitive Knowledge (EthCogKnw)	5
	Identity (EthIdent)	1
	Affect (EthAffect)	1
	Social Responsibility (EthSocRes)	1
	Social Interactions (EthSocInt)	4
	Global Citizen (EthGloCit)	1
	Threat	1
Total Items	**54**	

4 RESULTS

Prior to analysis, the data was cleaned, reverse-coded items were inverted, and the Likert-like responses were converted to a nominal scale. The responses were multiple choice and ranged from 'Strongly Disagree' to 'Strongly Agree,' which were changed to a 1 to 5 scale for the analysis portion of this paper. The analysis section of this research includes confirmatory factor analysis to determine the consistency of the questions within each scale, followed by paired t-tests to show that there are discernable differences between the GPI and the ethical questions we created in this research.

4.1 Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was performed to ensure internal consistency across the scales of the GPI, as well as to determine if the questions that were altered to create the EPI were consistent with the GPI survey items. CFA is a tool used to ensure that all items on a given scale are correlated to one another. The constructs described in the GPI are valuable insofar that they examine how a student perceives their own moral values, as well as how their moral values influence how they interact with other. We utilize confirmatory factory analysis in an attempt to define constructs that can later be used to see how students develop these abilities over time.

In our examination of the scales depicted in Table 2, we examined three goodness of fit statistics, the Root Mean Square Error of Approximation, (RMSEA), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI). The RMSEA is an absolute fit index based on chi-squared, degrees of freedom and the sample size.

Because the RMSEA is absolute, issues can arise when interpreting results from small models. However, with the given sample size (N=221), we also examined CFI and TLI, which has been shown to provide reasonable fits for models similar to ours in size [23]. An RMSEA of 0 indicates a perfect fit, while a moderate fit is generally considered under 0.08. The CFI and TLI are considered to have good fits if there are above 0.95 as they approach 1. Table 2 depicts that four of the six scales in the GPI containing more than one item were found to have a good fit, while cognitive knowledge potentially had a moderate fit. The cognitive knowledge and identity scales were not found to have great internal consistency, across the three measure goodness of fit statistics.

Table 2. Confirmatory factor analysis for GPI subscales

Scale	Measure of Goodness of Fit	Value	Classification
Cognitive Knowing (CogEp)	RMSEA	0.096	Not a Good Fit
	CFI	0.799	Not a Good Fit
	TLI	0.699	Not a Good Fit
Cognitive Knowledge (CogKnw)	RMSEA	0.070	Moderate Fit
	CFI	0.978	Good Fit
	TLI	0.955	Good Fit
Identity (Ident)	RMSEA	0.137	Not a Good Fit
	CFI	0.839	Not a Good Fit
	TLI	0.732	Not a Good Fit
Affect (Affect)	RMSEA	0.000	Good Fit
	CFI	1.000	Good Fit
	TLI	1.003	Good Fit
Social Responsibility (SocRes)	RMSEA	0.015	Good Fit
	CFI	0.999	Good Fit
	TLI	0.997	Good Fit
Social Interactions (SocInt)	RMSEA	0.030	Good Fit
	CFI	0.997	Good Fit
	TLI	0.990	Good Fit

To examine the EPI scales, researchers first substituted the relevant questions to create the ethical subscales based on the GPI scales. This was done by replacing the questions indicated in column 1 of Table 4 with the question indicated in column 2 of the table. The full questions can be seen in Appendix A. Similar to the finding from Table 1, both the cognitive knowing and the identity scales did not show good a fit, while cognitive knowing, affect, social responsibility, and social interactions all displayed a good fit across all three goodness of fit statistics.

Table 3. Confirmatory factor analysis for EPI subscales

Scale	Measure of Goodness of Fit	Value	Classification
EthCogEp	RMSEA	0.124	Not a Good Fit
	CFI	0.658	Not a Good Fit
	TLI	0.488	Not a Good Fit
EthCogKnw	RMSEA	0.037	Good Fit
	CFI	0.992	Good Fit
	TLI	0.985	Good Fit
EthIdent	RMSEA	0.074	Not a Good Fit
	CFI	0.934	Not a Good Fit
	TLI	0.891	Not a Good Fit
EthAffect	RMSEA	0.000	Good Fit
	CFI	1.000	Good Fit
	TLI	1.055	Good Fit
EthSocRes	RMSEA	0.000	Good Fit
	CFI	1.000	Good Fit
	TLI	1.028	Good Fit
EthSocInt	RMSEA	0.000	Good Fit
	CFI	1.000	Good Fit
	TLI	1.013	Good Fit

4.2 Paired Sample T-Tests

After examining the internal consistency within each subscale, it was important to ensure concurrent validity, that the EPI and GPI corollaries were measuring distinctly different measures. To do this we ran 19 separate paired sample t-tests, one for each EPI/GPI corollary to determine if there was a statistical difference between the means of each survey item. The results of the analysis found that of the 19 item pairs, ten pairs were significantly different with a 99% confidence interval, while an additional two survey pairs were significantly different with a 95% confidence interval.

Table 4. Paired sample t-test results across GPI and ethics equivalent

GPI Question	EPI Question	T	df	Sig. (two-tailed)
CogEp01	EthCopEp01	3.9773	220	0.0001**
Ident02	EthIdent02	-0.90545	220	0.3662
SocInt04	EthSocInt04	1.8829	220	0.0610
SocRes05	EthSocRes05	5.0611	220	0**
CogEp06	EthCogEp06	18.811	220	0**
CogKnw08	EthCogKnw08	-6.4766	220	0**
Threat10	EthThreat10	4.6933	220	0**
CogKnw13	EthCogKnw13	-2.8592	220	0.0047**
GloCit15	EthGloCit15	2.4108	220	0.01674*
CogKnw17	EthCogKnw17	-1.9928	220	0.0475*
CogEp19	EthCogEp19	2.6853	220	0.0078**
CogEp20	EthCogEp20	-0.15042	220	0.8806
CogKnw21	EthCogKnw21	-1.6311	220	0.1043
SocInt24	EthSocInt24	1.158	220	0.2481
CogKnw27	EthCogKnw27	-1.537	220	0.1257
SocInt29	EthSocInt29	-0.36889	220	0.7126
CogEp30	EthCogEp30	3.4401	220	0.0007**
Affect31	EthAffect31	3.6768	220	0.0003**
SocInt35	EthSocInt35	-8.2049	220	0**

*indicates a 95% confidence interval

**indicates a 99% confidence interval

5 DISCUSSION AND CONCLUSION

This study sought to examine how global and ethical perspective-taking parallel each other across a variety of dimensions. We first set out to show that the subscales of the GPI were internally consistent, to both create a baseline for consistency when we would start to alter items for the EPI, as well as bring the GPI to new settings to help determine the generalizability of the survey. While only 4 of the 6 subscales indicated good statistical fits, there is the possibility that this is due to a lower sample size (N~220), which we seek to expand upon in the future.

After determining the internal consistency of the GPI scales, our examination of the EPI scales, with the 19 items switched out for their corollaries, resulted in the same 4 subscales having good fit. In the case of the identity subscale, it is likely that because only 1 item was changed between subscales, and there was no statistical difference between the two from the t-test, the goodness of fits were results of nearly identical data. However, the same could not be said for the cognitive knowing

subscales. The first inclination was that there was the possibility that the survey items for each subscale were too similar, like the identity subscales, which could have led to the same goodness of fit results across the subscales. However, in the case of the cognitive knowing subscale, 5 of the 7 items were switched between scales, 4 of which had significant differences between the two subscales.
Of the 7 items that did not produce significant differences with the paired t-tests, three of the items were part of the social interaction subscale. There are a few reasons that this could have happened for this particular subscale. First and foremost, it is possible that the changes to the survey items were not impactful enough to make statistical differences. More likely, however, is the fact that these surveys were distributed electronically during the COVID-19 pandemic, during which a majority of classes transitioned to remote learning, and social interactions decreased drastically, both in and out of the classroom. Because of this, it is difficult to make any further claims as to why the social interaction subscales did not differ.
These results are the first step to identifying the relationship between global and ethical perspective-taking. We have provided evidence that when modifying items from the existing Global Perspective Inventory, we can create statistically different yet internally consistent subscales that measure aspects of both global and ethics education. Moving forward, we plan to continue to increase our sample size, so as to increase the internal consistency of the data and the external validity of the study. Additionally, we will continue to discuss and iteratively make changes to survey items to ensure statistical differences between the two. As we create distinctions between the two instruments, we will begin to examine how ethical and global constructs develop throughout the duration of higher education, and seek to expand our work to a plethora of other institutions, but within and outside of the United States.

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APPENDIX A. GPI/EPI SURVEY ITEMS

CogEp01	When I notice cultural differences, my culture tends to have the better approach. (R) *(R)-Reversed Item* *Note: This item was reverse coded from the original survey format (1 = Strongly disagree to 5 =strongly agree) to the correct format (1 = strongly agree to 5 = strong disagree).*
Ident02	I have a definite purpose in my life.
Ident03	I can explain my personal values to people who are different from me.
SocInt04	Most of my friends are from my own ethnic background. (R)
SocRes05	I think of my life in terms of giving back to society
CogEp06	Some people have a culture and others do not. (R)
CogEp07	In different settings what is right and wrong is simple to determine. (R)
CogKnw08	I am informed of current issues that impact international relations
Ident09	I know who I am as a person.
Threat10	I feel threatened around people from backgrounds different from my own. (R)
Comfor11	I often get out of my comfort zone to better understand myself.
Ident12	I am willing to defend my own views when they differ from others.
CogKnw13	I understand the reasons and causes of conflict among nations of different cultures.
SocRes14	I work for the rights of others.
GloCit15	I see myself as a global citizen.
CogEp16	I take into account different perspectives before drawing conclusions about the world around me.
CogKnw17	I understand how various cultures of this world interact socially.
Ident18	I put my beliefs into action by standing up for my principles.
CogEp19	I consider different cultural perspectives when evaluating global problems.

CogEp20	I rely primarily on authorities to determine what is true in the world. (R)
CogKnw21	I know how to analyze the basic characteristics of a culture.
Affect22	I am sensitive to those who are discriminated against.
Affect23	I do not feel threatened emotionally when presented with multiple perspectives.
SocInt24	I frequently interact with people from a race/ethnic group different from my own.
Affect25	I am accepting of people with different religious and spiritual traditions.
SocRes26	I put the needs of others above my own personal wants.
CogKnw27	I can discuss cultural differences from an informed perspective.
Ident28	I am developing a meaningful philosophy of life.
SocInt29	I intentionally involve people from many cultural backgrounds in my life.
CogEp30	I rarely question what I have been taught about the world around me. (R)
Affect31	I enjoy when my friends from other cultures teach my about our cultural differences.
SocRes32	I consciously behave in terms of making a difference.
Affect33	I am open to people who strive to live lives very differently from my own life style.
SocRes34	Volunteering is not an important priority in my life. (R)
SocInt35	I frequently interact with people from a country different from my own.
EthCogEp01	When I notice differences in values, I generally believe my values are better.
EthIdent02	I have a distinct set of ethical convictions.
EthSocInt04	Most of my friends share my point of view about day-to-day issues.
EthSocRes05	I think of my life in terms of justice.
EthCogEp06	Some people are ethical and others are not.
EthCogKnw08	I am informed of/about current moral issues in society.
EthThreat10	I feel threatened around people who display values different from my own.
EthCogKnw13	I understand the reasons and causes of conflict among people with different values.
EthGloCit15	I see myself as part of a like-minded community.
EthCogKnw17	I understand how diverse groups of people interact in society.

EthCogEp19	I consider different ethical perspectives when evaluating interpersonal problems.
EthCogEp20	I rely primarily on authorities to determine what is right or good for me to do.
EthCogKnw21	I know how to analyze the basic characteristics of value systems.
EthSocInt24	I frequently interact with people that hold values different from my own.
EthCogKnw27	I can discuss value differences from an informed perspective.
EthSocInt29	I intentionally involve people with different viewpoints in my life.
EthCogEp30	I rarely question what I have been taught about right and wrong.
EthAffect31	I enjoy when friends with other perspectives or beliefs teach me about our differences.
EthSocInt35	I frequently interact with people who think differently from me.

UNIVERSITY RESEARCH CULTURE AS AN ESSENTIAL IMPACT FACTOR FOR HIGH-QUALITY ENGINEERING EDUCATION

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***Keywords**: University research culture, faculty engagement in engineering research, faculty development.*

ABSTRACT

Two missions of universities are generating new knowledge and disseminating it, hence the importance of research and publications activity. The current prevailing focus on research in academia - sometimes exaggerated to the detriment of teaching – is a debatable issue. Some benefits of promoting university research culture are undeniable; for example, faculty, by being involved into active research, can have better access to the state-of-the art knowledge in their field. In addition, active university research culture contributes to developing students' critical thinking and better equips students with the skills necessary to work in rapidly developing engineering areas. Thus, the developed university research culture offers an enriching environment for the students and positively contributes to the education process. In this paper we aim to evaluate the research culture of several Russian universities and to define a suitable metric for describing the level of their research culture development – the research culture index (RCI). For the universities with RCI > 1 the research culture is well established and needs further nurturing. For the universities with RCI<=1 the research culture is rudimental and needs to be established fully. We choose to focus on Scopus publications and age group of the faculty in order to compare various types of universities in Russia, including engineering schools and universities with engineering departments. Our findings clearly illustrate the challenging process the "old" universities had to go through to develop a research culture. The paper offers recommendations for all types of the universities under considering on how to improve their research culture.

1 INTRODUCTION

1.1 Background

Currently there are over 950 universities in Russia [1] and over 29,000 globally [2] and the competition among them is strong [3]. The Higher Education system in Russia has been transformed over the past 20 years, forcing organizations previously primarily focused on educational to become active in research [4]. In the last decades many Russian universities succeeded in drastically improving their publication records. However, the extent to which the internal research culture is affected remains little studied.

The Lotka's law sometimes is applied to assess the research production inequality [5,6,7]. The law states that "... the number (of authors) making *n* contributions is about $1/n^2$ of those making one; and the proportion of all contributors, that make a single contribution, is about 60 %." [8] Though it doen't allow for the internal research culture analysis.

In this paper we investigate the state of the university research culture in several Russian universities. We imply that a vibrant research culture is essential for the quality modern education and talent attraction [9], in particular in rapidly evolving areas such as engineering. Further, we propose activities to improve the research culture including faculty development activities, students' engagement in research, and organizational changes to boost research synergy effects at the universities.

1.2 Research culture definition

Before proceeding to the exploration of the research culture of the universities, we would like to clarify what we define as a "research culture". In this paper we adopt the following definition: "Research culture is a set of values, beliefs, assumptions and behaviors related to the implementation of research that owned by the organization collectively" [10].

Therefore, we investigate not just the cumulative research output of the university in terms of quality publications, but also identify the fraction of the full-time faculty members engaged in an active research, based on their publication output. We assume that once the fraction of such faculty members is large enough, the university naturally develops a set of collective behaviors supporting and promoting scientific curiosity: spontaneous research discussions during the coffee-breaks and lunches, official and unofficial research seminars, incorporation of the recent scientific discoveries in the educational lectures, etc. We also assume that the part-time faculty-members have little or no effect on the research culture of the university. This is due to a common practice in Russia where part-time faculty members are only nominal; they mention the affiliation of the University in their papers, while almost never being present in person, and thus unable to be actively engaged in or to affect collective behavior in anyway.

1.3 The purpose of the study

The purpose of current research effort is to identify a metric for the assessment of the internal university research culture. For the universities where the research culture is immature we suggest the ways to improve it in a sustainable manner. The results of this study can be utilized by the universities in transition from a purely educational to an educational-research model.

2 METHODOLOGY

2.1 The Universities involved in the study

The data for the study were collected between November 2019 and March 2020 from 5 Russian universities. Table 1 summarizes the universities participated in this study.

Table 1. The Russian universities participated in the study

Label	Short description	Current position in QS BRICS[2]	Number of Scopus publications per faculty[3]
A	Polytechnic University at a metropolis in the North-West of Russia, 13,000 students, 419 faculty members	301-350	0,28
B	Polytechnic University at a metropolis in the East of Russia, 9,500 students, 650 faculty members	150-170	0,64
C	Federal University in the North of Russia, 10,500 students, 700 faculty members	201-210	0,34
D	Department of a major university in the capital, 29,000 students, 1,500 faculty members	30-40	0,86
E	Private university at a metropolis in the North-West of Russia, 110 students, 36 faculty members	-	0,46

2.2 Data collection

We have collected data on the full-time faculty members including their age group, and the number of the scientific publications indexed by Scopus in the last 3-5 years. We choose Scopus database as being the main metric affecting the university budgeting system in Russia. This metric is rather arguable and, unfortunately, leaves aside a lot of publications in engineering education research.

In addition, three of the universities mentioned in this research (Universities A, C, and D) had conducted a survey among the faculty members aiming to identify the challenges for the faculty preventing them from more active research, and asking about ways to support for helping faculty to improve their research record.

Over 32% of the faculty members anticipated in the survey at the university A, 49% at the university C, and 21% of the faculty of the department under consideration at the University D.

2 *https://www.topuniversities.com/university-rankings/brics-rankings/2019*
3 *http://indicators.miccedu.ru/monitoring/*

The questionnaire of the survey is presented at the Appendix 1.

3 RESULTS AND DISCUSSION

3.1 Resent publication activity by the faculty

In this study we explored the research activity using the Scopus publication database. We tracked publications only by the faculty members with a primary affiliation at the university. We did so because it is common in Russia for faculty never to be physically present at their secondary affiliate institutions and not affect their research culture, while often contributing substantially to the overall publication metrics of those secondary institutions.

For example, a prominent scientist publishes actively with the university affiliation, but has a primary affiliation somewhere else. Such person will contribute a lot to the overall publication record of the university, but will not affect the research culture – will not communicate with the peers at the university, will not inspire the younger scientists, will not share their experience, and will not engage in joint research efforts.

Finally, here we have the significant limitation of not being able to track individual papers, but rather the number of the publications by every author, i.e. the joint paper by two researchers of the university is counted as two papers. This gives us a max estimation of the papers produced in the university.

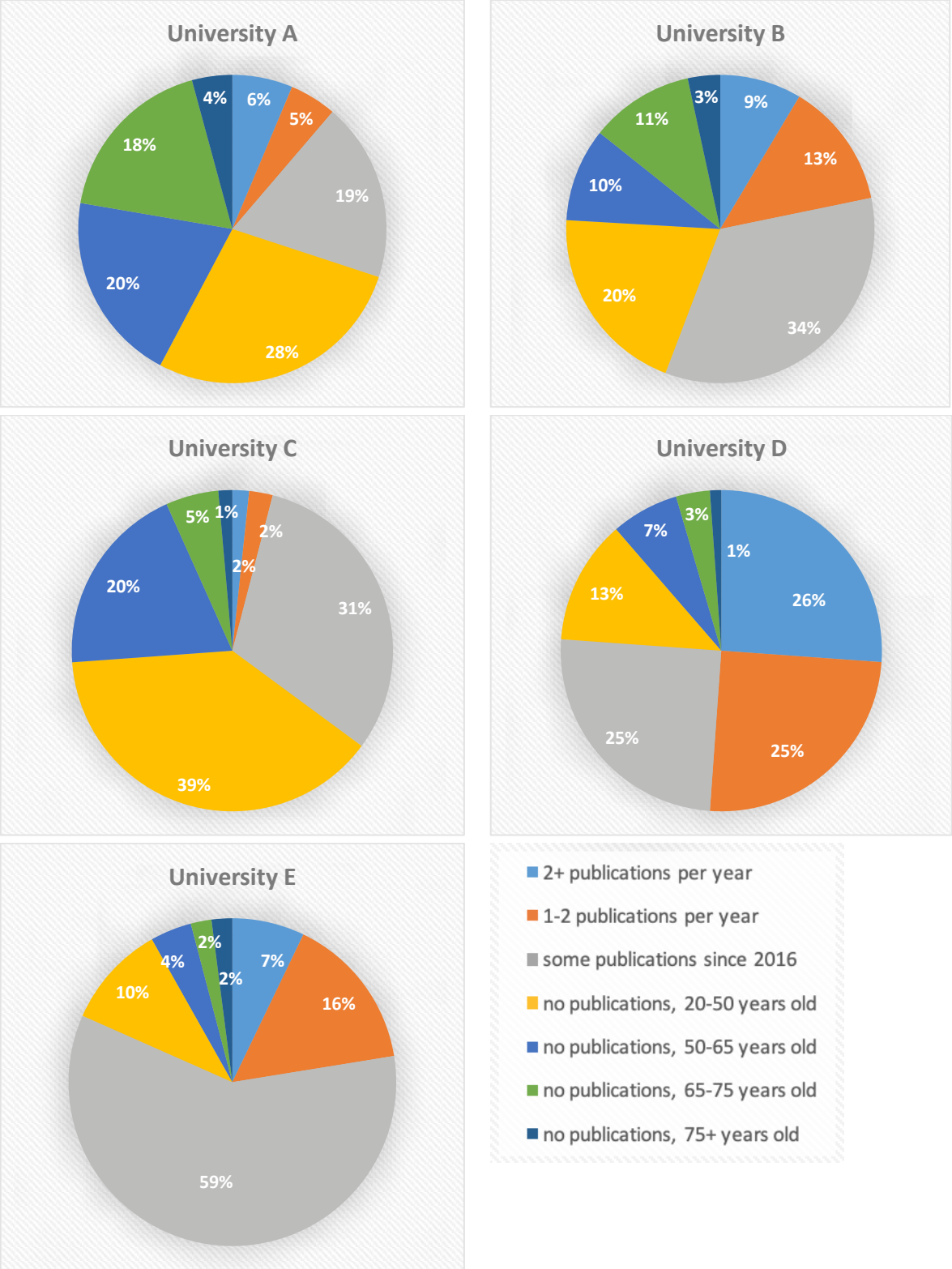
In order to simplify the comparison between the universities we define the following seven categories:

- Faculty members publishing at least 2 or more publications per year in 2018-2019
- Faculty members publishing 1 to 2 publications per year in 2018-2019
- The rest of the faculty with publications in 2016-2019
- Faculty with no publications in 2016-2019, and 20-50 years old
- Faculty with no publications in 2016-2019, and 50-65 years old
- Faculty with no publications in 2016-2019, and 65-75 years old
- Faculty with no publications in 2016-2019, and 75+ years old

Note that the retirement age set by the government in Russia since 2020 is 65 years old for males and 60 years old for females. However, the faculty are rarely stop working full time at the university after reaching the retirement age.

Table 2 summarizes the results of the comparison of the universities A, B, C, D, E on seven categories.

Table 2. Recent publication activity comparison



3.2 Defining the University research culture index

A metric one can propose by looking at the Table 2 charts: the ratio between the faculty who publishes regularly (2+ papers and 1+ papers per year) and the faculty without publications. The index highlights how visible the faculty performing an active research are among the peers at the university.

Table 3. The University research culture index (RCI)

University	A	B	C	D	E
RCI	0,16	0,5	0,06	2,13	1,28

The universities demonstrating an index value greater than 1 are the universities D and E. This means that the number of scholars of the departments actively engaged in the research is larger than those who do not publish due to some reasons. We can posit that the values, beliefs, assumptions and behaviours related to the implementation of research are solidly embedded in the culture of these universities. However, at the University E 59% of the faculty are “on pause”, not publishing for the last 2 years.

For other universities the faculty population is dominated by people with few or no research output at all. This is a warning sign. Even when the overall the number of publication per faculty member is rather high, like for the University B with Scopus papers per faculty of 0,64 (see Table 1), the internal university research culture index is low, 0,5 < 1. The main contribution to research output is coming from the part-time faculty members.

Another example: The Universities C and E have similar publications per faculty ratios (0,34 and 0,46 respectively, 1,35 times difference). However, the research culture index is drastically different being 0,06 and 1,28 receptively (over 20 times difference).

The metric we propose is very rough and doesn’t not allow for the detailed insight into the nature of the problem. However, it does indicate that there IS a problem, while the traditional indicators of the university overall may demonstrate a positive picture.

3.3 Analysing the faculty survey data

The Universities A, C and D have conducted surveys of their faculty members. The surveys were designed to identify the key factors preventing faculty members from producing Scopus publications and, for those publishing already, the factors preventing them from more active research.

Here we would like to mention that there are very few faculty members at each of the universities publishing more than two Scopus publications per year. For an average European scholar at the same time, we would expect to find 3 to 8 Scopus publications per year [11].

Please refer to appendixes 2, 3 and 4 for the detailed report on the faculty surveys at the universities A, C and D.

About half of the respondents at University A indicated the lack of time as a key reason for poor research productivity. The student to faculty ratio at the University A is over 30, which does indicate a problem with a teaching load for faculty. It is also inspiring to see that the faculty are more interested in professional support from University rather than increase in monetary stimulus.

For University C the financial aspects seem to be the most critical. Even though the average compensation for the faculty is 55% higher than the median for the region, it is still low compared to other universities included in this study. Many faculty members ask to reduce a teaching load, however at this university the students per faculty ratio is 14 and the teaching load should be normal. Therefore, the feeling of “no time” is probably related to time management issues and extra administration activities.

University D is the “healthiest” in terms of the research culture. The financial issues are less important for the faculty too. The average faculty compensation is over double the average in the region. However, there is a lack of understanding of why research is important and how it can contribute the faculty career.

3.4 Recommendations for improving the research culture

Firstly, for the universities announcing research as one of their key missions, we recommend that every newly hired faculty member should demonstrate a track record of quality publications every year, at least one per year. Secondly, we encourage all universities/organizations to identify their uniqueness and to emphasis is (maybe it is sustainable development culture, rather than research). Finally, below we offer sets of recommendations for the universities with RCI above and below 1.

3.4.1 Recommendations for the Universities with RCI=>1

General recommendations for the universities having RCI => 1:

a. Keep nurturing the research culture and emphasis the importance of research for the faculty members.
b. Clarify the reasons preventing the inactive faculty from engaging in research
c. Engage the inactive faculty in research by organizing activities, like open research seminars, yearly awards for the best first publication, improve international collaborations etc.
d. For the faculty focused on teaching try to encourage them to explore possibilities of doing active research in the area of higher education.
e. Engage students in research early. Support students’ initiatives in exploring natural curiosity.
f. Widen the multidisciplinary research collaborations with other national and international universities, for example Grand Engineering Challenges [12].

3.4.2 Recommendations for the Universities with RCI<1

The universities with RCI <1 are lacking shared values, beliefs, assumptions and behaviors related to the implementation of research. The primary goal for such universities is to build an internal research culture and to embed that culture solidly in the university.

We recommend developing an action plan for the next 3-5 years focused on improving research culture. The activities would be focused on different faculty groups:

1) For those who publish at least one paper per year:
    - Review the teaching load for those who publish actively
    - Establish a university fund supporting travelling for the most important conferences to support publications
    - Introduce a regular seminar helping the authors to generate new ideas
    - Engage faculty in Engineering Education Research as an additional research area
    - Support national and international research collaborations
2) For those who publish occasionally or do not publish and are under 50 years old
    - Offer a training on academic writing
    - Offer a workshop on how to submit a first research paper
    - Organize activities assisting in finding co-authors within the university and beyond
    - Organize regular social activities helping to promote research culture
3) For those without publications and 50-65 years old
    - Offer access to the same trainings as above
    - Engage actively in the mentoring and supervision activities of the students and junior faculty in terms of teaching
    - Encourage to explore possibilities of doing active research in the area of higher education – offer thematic trainings.

In particular, for University A 42% of the faculty population is over 50 years old and without experience of publishing research results. This is an alarming signal and the revision of the faculty composition is crucial for the university to move towards the research and teaching paradigm.

4 SUMMARY AND CONCLUSIONS

In this paper we have analysed Scopus publications by full-time faculty members at five Russian universities, including two technical universities and two universities with large engineering departments. Based on the data, we proposed a research culture index (RCI), as a ratio between actively-publishing and non-publishing faculty members at the university. Here we suggest that when RCI is close or greater than 1, the university enjoys a developed research culture. For the universities with RCI < 1 the organization has immature research culture, even when the total number of publications per faculty is high.

In addition, we have conducted faculty surveys at three of the universities in order to clarify the factors that prevents the faculty from publishing (or publishing more actively) and the assistance the university can offer to encourage publications. Based on the survey results and the RCI value, we proposed recommendations for the universities on how to improve their internal research culture. We assert, that a vivid inspirational environment, supporting natural curiosity of the students at the university is essential for quality education.

We encourage colleagues to apply the described methodology to analyse their universities/organizations. The proposed research culture index is easily applicable and could provide an interesting insight into the nature of the organization. The proposed method could be especially interesting for the universities in transition from an educational format to one of both research and teaching.

While providing consultancy services for the universities in Russia the authors faced a strong resistance in engaging faculty in research. The vast majority of the faculty are focused on teaching only and find it impossible to conduct research in engineer the same time parallel. Most of the faculty teaching engineering have never considered engineering education as a possible research focus. Among other action items we suggest to introduce faculty to research in engineering education, using the data from their primary activity.

Currently the implementation of the recommendations is in progress at University A. The results of the effort will be described in following publications.

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Appendix 1

The faculty survey

Please, underline your age group: (20-29), (30-39), (40-49), (50-59), (60-64), (65-75), (75+)

Please, underline your gender: Male, Female

1. Do you have an experience of publishing in English in venues indexed in Scopus?

2. Do you have at least 4 publications in Scopus in the last two years? If yes, please, indicate how many.

3. What is stopping you from starting to publish (publish more) in venues indexed in Scopus? Please choose no more than 3 items:
   a) Not enough time;
   b) I don't see value in such publications for my career;
   c) Difficult to write in English;
   d) Why even bother? Anyway, my article surely won't be accepted in such journals;
   e) Not enough ideas for more publications;
   f) No experience of submitting papers to Scopus journals;
   g) The process is costly while the monetary stimulus from the university is small;
   h) No funding to travel to a conference or for paper submission;
   i) I conduct research on classified topics that can't be disclosed;
   j) Your reply _____

4. What would help you to start publishing/publish more papers in Scopus venues? Please choose no more than 3 items:
   a) Lower teaching load for those who publish a lot;
   b) Provide assistance in establishing contacts with successful research groups;
   c) Increase of the monetary stimulus for publications;
   d) Help with new ideas generation;
   e) Academic Writing Course in English offered by the university;
   f) Guaranteed full/partial financing for trips to the best conferences where the papers were accepted;
   g) Recommendations of Scopus venues where article are likely to be accepted;
   h) Workshops on how to write a paper for a Scopus journal and submit it;
   i) Workshops on how to publish research on classified topics;
   j) Clarify how publications in Scopus will help my career in the university;
   k) Your reply _____

Appendix 2

The faculty survey results from University A

At the university A over 38% of the faculty members participated in the survey. Approximately 2/3 of the respondents were from the category that does not publish and is under 50 years old, and about 1/3 from those who have the experience of Scopus publications already. Here we present the top 4 most popular answers.

Among the respondents without any experience of Scopus publications the most common preventing factors are:

- No experience of the paper submission in the international venue – 54%
- No time for research – 42%
- No financial support for attending conferences – 42%
- Difficult to write in English – 31%

The assistance they are looking for from the University:

- Professional training on how to submit the publication – 40%
- Academic writing course – 38%
- Recommendations for the journals/conferences to publish – 32%
- Assistance in establishing contacts with other research groups – 30%

Among those with Scopus publications already:

- No time for research – 55%
- No financial support for attending conferences – 42%
- Not enough monetary stimulus from the University for publications – 33%
- Lack of new ideas – 33%

The assistance they expect from the University:

- Increase of the monetary stimulus for publications – 42%
- Financial support for attending conferences – 41%
- Lower teaching load – 34%
- Help with new ideas generation – 28%

Appendix 3

The faculty survey results from University C

At University C 49% of faculty members participated in the survey. Here we present the top 4 most popular answers.

The respondents without any experience of Scopus publications the most common preventing factors:

- No financial support for attending conferences – 55%
- Not enough monetary stimulus from the University for publications – 55%
- No time for research – 42%
- Difficult to write in English – 35%

The assistance they are looking for from the University:

- Increase of the monetary stimulus for publications – 46%
- Financial support for attending conferences – 44%
- Lower teaching load – 39%
- Recommendations for the journals/conferences to publish – 33%

The respondents with Scopus publications experience:

- No time for research – 68%
- Not enough monetary stimulus from the University for publications – 58%
- No financial support for attending conferences – 49%
- Difficult to write in English – 21%

The assistance they expect from the University:

- Increase of the monetary stimulus for publications – 54%
- Lower teaching load – 50%
- Financial support for attending conferences – 44%
- Recommendations for the journals/conferences to publish – 33%

Appendix 4

The faculty survey results from University D

At the department of University D 21% of the faculty members participated in the survey. The total number of the responds is just 23 therefore the statistical reliability is low.

The respondents without any experience of Scopus publications the most common preventing factors:

- Difficult to write in English – 60%
- No experience of the paper submission in the international venue – 60%
- Don't see the value for my career – 40%

The assistance they are looking for from the University:

- Assistance in establishing contacts with other research groups – 50%
- Academic writing course – 50%

Among those with Scopus publications already:

- No time for research – 88%
- Don't see the value for my career – 29%
- Lack of new ideas – 23%

The assistance they expect from the University:

- Recommendations for the journals/conferences to publish – 35%
- Increase of the monetary stimulus for publications - 29%
- Assistance in establishing contacts with other research groups – 12%

VALUES AND COMPETENCES RELATED TO SUSTAINABILITY AMONG ENGINEERING STUDENTS

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Keywords: *Sustainability, sustainable development, competences*

ABSTRACT

Current estimations e.g. on climate change and loss of biodiversity have transformed sustainability as one of the most influential global trends. For example, universities promote sustainability as their core value and include sustainability related content in their curricula. These actions are consistent with SDGs (Sustainable Development Goals) proposed by United Nations. Engineers are essential for achieving SDGs since their skills and know-how are required to present estimations, develop and implement technological solutions and transform processes. Accordingly, engineering education is in key role to foster these competences and related values.

Hence, we study in this paper values and competences related to sustainability among engineering students in Finland. Our research questions are: How do engineering students perceive the importance of sustainable development for their future professional career and how have they developed in studies? Are engineering students willing to advance SDGs as part of their upcoming career? To answer these questions, data from two separate surveys are analysed. The data of the first survey was collected during 2016–2018, which focused on engineering students on the brink of graduation. The second survey focused on engineering students from the second year onwards and the data was collected in 2019. The preliminary analysis shows that engineering students do not perceive sustainability as an important competence in engineering careers. Accordingly, their competences related to sustainability evolve less during studies compared with other engineering skills and competences. However, students expressed their will to advance sustainable development through their professional careers.

1 INTRODUCTION

Climate change alongside other environmental issues have set sustainability as a global megatrend. Higher education plays a central role to share skills and knowledge to ensure sustainable development [3] and it has responsibility to spread awareness of the importance of conserving the environment [9]. Hence, Sustainable Development Goals (SDGs) proposed by the United Nations [11] are now relatively common in the strategies, curricula and other operations that higher education institutions have implemented.

Engineers have essential role in attaining SDGs, because activities that advance industrial development are rooted in engineering [1]. Hence, values and competences related to sustainable development would need to become integral part of engineering education in higher education institutions. This would require a gradual and long-term change of educational paradigm towards sustainability [5]. Some universities have integrated sustainable development into their curricula decades ago [4], whereas others have not [2]. In Finland, sustainable development is relatively new trend in engineering education.

Prior study in one Finnish university revealed that sustainable development is one of the competencies that engineering graduates perceive as least important [8]. Accordingly, academic staff and industrial employers considered sustainable development among the least valued competencies although industrial employers expected its importance to grow in future. While the values among engineering graduates, academic staff and industrial employers appear to be in line, these findings inspire to study the phenomenon futher. Hence, this study aims to discover values and competencies regarding sustainable development among engineering students in Finnish universities. The development of competencies during engineering studies between 2016–2018 and the values of engineering students in 2019 were investigated by analysing responses for nationwide surveys conducted by the Academic Engineers and Architects in Finland (TEK).

2 METHODOLOGY

2.1 Methodology

In this study, we assess values and competences related to sustainability among engineering students in Finland. Our research questions are: How do engineering students perceive the importance of sustainable development for their future professional career and how has sustainability developed in their studies? Are engineering students willing to advance SDGs as part of their upcoming career?

To answer these questions, data from two separate surveys; namely, TEK Student Survey and TEK Graduate Survey are analysed. Both surveys include sustainability-related questions that provide insights to our research questions. We also assess how competences and values are affected by background factors such as field of study or gender. Both surveys cover data from all Finnish universities that offer engineering education. These include five Aalto University schools: Arts, Design and Architecture (Aalto ARTS), School of Science (Aalto SCI), School of Chemical Engineering (Aalto

CHEM), School of Electrical Engineering (Aalto ELEC) and School of Engineering (Aalto ENG). Other universities that offer engineering education include Lappeenranta-Lahti University of Technology (LUT), Tampere University (TUNI), University of Turku (UT), University of Oulu (UO) and Åbo Akademi University (ÅAU).

2.2 TEK Student Survey

TEK Student Survey is an annual survey for all of TEK's student members excluding first year students. The survey is used to measure how well engineering students get employed during their studies and how their job experience is contributing to the development of their skills and competences regarding later career. This paper examines data from the 2019 TEK Student Survey in which the topic was focused on sustainable development. The response rate of the survey was 20 % with 3393 respondents.

2.3 TEK Graduate Survey

TEK and the Finnish higher engineering education institutions have conducted a joint feedback survey, TEK Graduate Survey, on a national scale for engineering graduates since 2011. The survey assesses various aspects of engineering education including employability of graduates, satisfaction with studies and study guidance, and development of skills and competences during studies. The survey is sent to all M.Sc. (Tech) graduates in Finland. In this paper, we examine results from surveys between 2016–2018. The answer rates were 68 % in 2016, 78 % in 2017 and 82 % in 2018. The survey is continuously open so that graduates can answer the survey in the brink of their graduation and the data is processed to yearly reports afterwards.
The survey does not explain in detail the skills, competences and knowledge that the respondents are asked to evaluate. Hence, the respondents might have different perceptions what the specific skills, such as knowledge in sustainable development, means.

3 RESULTS

3.1 Importance of promoting sustainable development in engineering careers

TEK Student Survey in 2019 included questions about students' attitudes toward promoting SDGs in their career. The results of the survey are collected in Table 1. The results are presented by gender and by university. The original survey questions, which are abbreviated in Table 1, are as follows:
How important is it to you to be able to further the following Sustainable Development Goals in your career?

- **sustainable economic development**: balanced economic growth without incurring debt or overusing capital stock while taking in account future generations and the carrying capacity of the environment
- **sustainable social development**: reducing inequality between people and guaranteeing adequate livelihood, appropriate healthcare, availability of education and fulfilment of fundamental rights

- **environmentally sustainable development**: sustainable use of natural resources and taking into account the limits of the planet
- **cooperation and partnerships** in furthering sustainable development goals
- furthering **peace, fairness and good governance**

Table 1. Importance of furthering sustainable development goals through career. (1= not at all important, 5 = very important)

	sustainable economic development	sustainable social development	environmentally sustainable development	cooperation and partnerships	peace, fairness and good governance
Male, n=1931	3,66	3,46	3,94	3,55	3,69
Female, n=908	3,89	3,92	4,41	3,84	4,00
TOTAL, n=2802	3,73	3,61	4,09	3,64	3,79
Aalto TOTAL, n=1111	3,75	3,64	4,17	3,67	3,79
Aalto ARTS, n=44	4,06	4,25	4,83	4,11	4,42
Aalto SCI, n=288	3,66	3,60	3,96	3,51	3,78
Aalto CHEM, n=201	3,84	3,72	4,39	3,77	3,76
Aalto ELEC, n=229	3,70	3,57	3,99	3,62	3,83
Aalto ENG, n=318	3,76	3,62	4,24	3,73	3,71
LUT, n=383	3,66	3,48	4,08	3,65	3,68
TUNI, n=972	3,65	3,48	4,02	3,57	3,71
UT, n=133	3,76	3,70	4,05	3,55	3,92
UO, n=448	3,81	3,75	4,07	3,66	3,89
UVA, n=89	3,80	3,63	4,03	3,78	3,88
ÅAU, n=94	4,05	3,90	4,28	4,04	4,22
Other, n=153	3,80	3,80	4,02	3,62	3,86

Several interesting observations can be extracted from Table 1. For example, female respondents are much more interested in pursuing a sustainable career. As women are underrepresented in engineering studies in Finland and represent approximately only one fourth of total student population [7], the total results are closer to the male average than female average.

Besides gender, the study field of respondents has a significant effect on how important sustainability as a part of their engineering career is. The study fields with the most interest towards promoting sustainability include students of Architecture, Environmental Engineering, Chemical Engineering and Biotechnology, and Energy Engineering. The least interested students in promoting sustainability were students of Mechanical Engineering, ICT and Electrical and Automation Engineering. It should also be noted that the fields of science that value sustainability high are also more

balanced in gender while the fields of science that value sustainability low tend to have very low number of female students.

When comparing results between universities or schools, the respondents from Aalto ARTS were most interested in promoting sustainability through their career. The students of technology in Aalto ARTS include mostly students of architecture, and unlike the average field of technology in Finland, students of architecture are mostly female. But even compared to the average female respondent, the students of Aalto ARTS were more oriented to furthering sustainability in their career. When looking at the universities with larger student population including Aalto TOTAL, TUNI, UO and LUT, the ones that stand out with more positive attitudes towards sustainability are UO and Aalto TOTAL. This finding can not be solely explained by gender and field of education since e.g., UO does not have a large share of female students or students in fields of science that are sustainability-oriented.

3.2 Development of skills in sustainable development in engineering education

The TEK Graduate Survey measures expertise and skills development and importance in one's own career by evaluating 29 different factors. The graduates assess all factors from the following three standpoints: 1) what is the perceived importance of the factor in their own career, 2) how has the expertise or skill developed in formal studies and 3) how has the expertise or skill developed through work experience during studies. In Fig. 1, the average values of each standpoint of all rated skills and expertise are displayed.

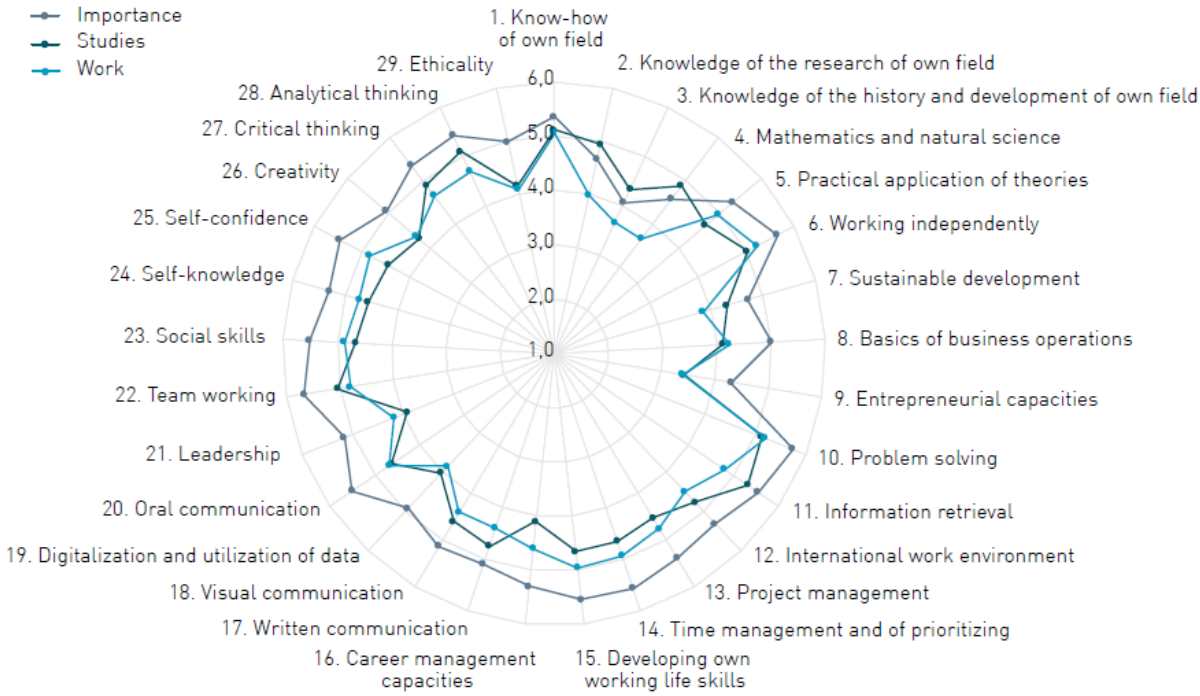

Fig. 1. Expertise and skills: importance and development of skills, competences and knowledge.

Further in our analysis we only focus on factor 7, Sustainable development, for which the official form in the survey is "Knowledge in sustainable development". Fig. 2 presents the importance and development of knowledge in sustainable development

compared to the average importance and development of all skills in annual surveys between 2016–2018. As can be seen from the results, all measured dimensions of knowledge in sustainable development have increased gradually every year while the the average development of skills have mostly remained stable in the three year period, but even still the development of knowledge in sustainable development is lagging behind the average skill.

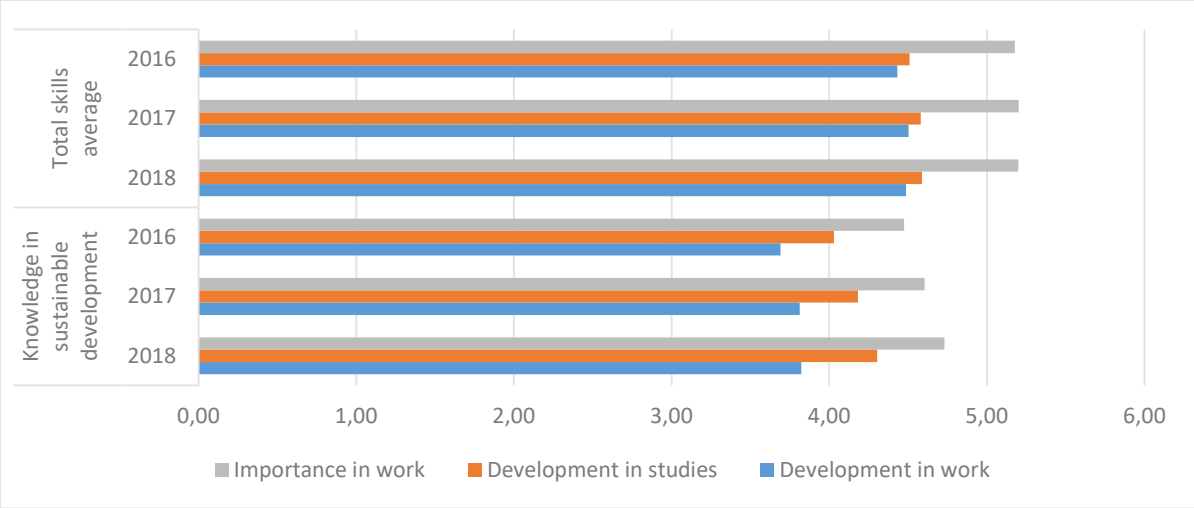

Fig. 2. Importance and development of the average skill and knowledge in sustainable development, comparison of 2016–2018.

The results indicate that the perceived importance of sustainable development is low compared with many other competences; however, it has grown each year. Also the development of these competences through formal education and through work experience gained during studies has risen every year although they develop less than many other competencies.

Since we perceived such differences between male and female respondents in importance in furthering sustainable development in career, we will again examine if there are gender differences. To demonstrate the possible differences, we only look at data from one year, 2018. The results are presented in Fig. 3.

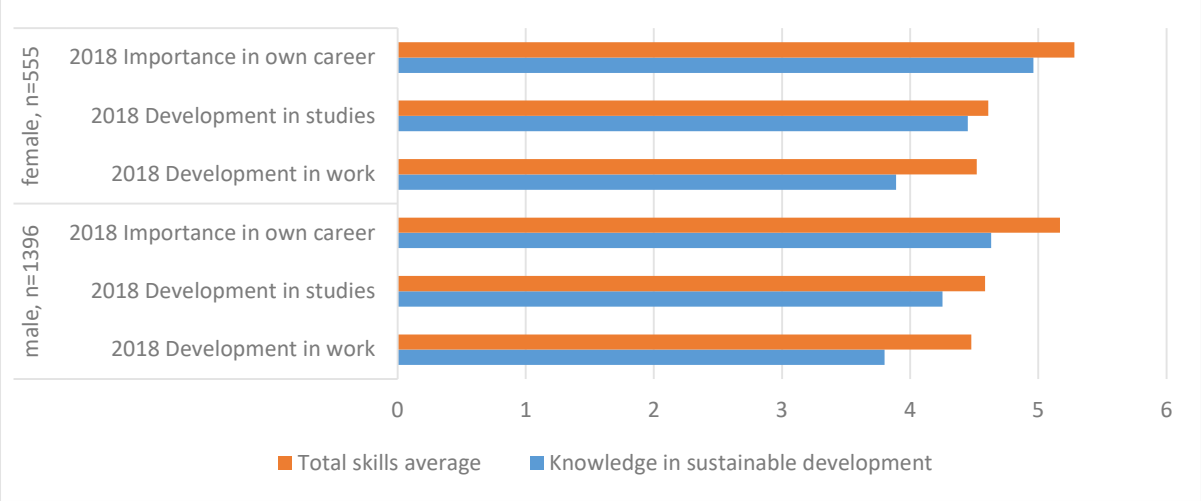

Fig. 3. Importance and development of the average skill and knowledge in sustainable development. Differences between male and female respondents.

The difference in average importance or development of skills between male and female respondents is very small, but we observe more significant differences when looking at the specific skill. In the case of knowledge in sustainable development, both the perceived importance in own career and the development in formal studies are closer to the average skill development for female academic engineers.
In addition to gender differences, there are once again differences between fields of studies similarly to that of the TEK Student Survey data. The graduates from Architecture and Landscape Architecture, Materials Technology, Energy Engineering, Environmental Engineering and Chemical Engineering perceive the importance and development of knowledge in sustainable development in the higher end of the scale, whereas Science and Engineering, Biotechnology and Information Technology rate them in the lower end of the scale.

3.3 Concluding remarks on survey results

The survey results of TEK Graduate Survey and TEK Student Survey are not comparable as they assess very different factors, but the contradictions between the expectations of furthering sustainability and the perceived importance in work and development through formal studies is a very interesting phenomenon. Promoting sustainability in future engineering careers is important or very important for most of the students, but knowledge in sustainable development is perceived as one of the least important skills in engineering careers. It is also important to highlight that engineering students in Finland have worked approximately two years in their field of study by the time of graduation, so the graduates are at least somewhat qualified to assess the importance of different skills at the beginning of their engineering careers.

4 SUMMARY AND DISCUSSION

Engineering students are very willing to promote different aspects of SDGs through their own careers. Reflecting to this trend, higher engineering education in Finland seems to be developing in the desired direction with students reporting increasing values in the development of knowledge in sustainable development each year. However, sustainable development is currently perceived as one of the least important skills in one's own career, which is to say that graduates do not expect that they get to promote sustainability in their careers, at least when compared to other competences. An intriguing question that is left unanswered is: how well the Finnish labour market is equipped to meet the expectations of those graduates that wish to promote sustainability in their careers? Many graduates might be disappointed in the short run as many jobs do not embrace sustainability, but hopefully in the long run increasing number of jobs will play a part in building a more sustainable world.
Both gender and field of study were discovered as factors that affect how engineering students value sustainability in their careers. Female respondents valued sustainability more than male respondents. This finding is consistent with prior studies on values among engineers and engineering students. For example, Finnish engineers in general do not consider the use of ethics in their work as important as

other competences and capabilities; however, women perceive ethics more important than men [10]. As attracting more female students is continuously pursued by many academic organizations, we can expect the importance of promoting sustainability in engineering careers to be even higher in the future.

There are also differences in values towards sustainability between engineering students in different universities. In this study, we could not provide any insights to what causes these differences, as they are not attributable to our findings in differences on gender and field of study. For example, fostering competencies related to sustainable development during engineering education would require intensifying collaboration between teachers in curriculum development [6]. A further study on what causes students in individual universities, such as the University of Oulu, to stand out in the importance on promoting sustainable development in careers would be very interesting.

The results presented in this study are consistent with prior value studies conducted by TEK. The TEK Student Survey of 2017 focused on the values of students and the main finding was that the top 3 values for engineering students are benevolence, universalism and work. With the importance of benevolence and universalism, it was expected that the importance of promoting sustainability in engineering careers would be high. According to values research, not only do people with the similar values choose similar fields of studies, but also the values of students in a given field of science tend to equalize over the course of studies [12]. Therefore the results presented in this paper do not provide insights to how engineering studies in general or in a specific engineering profession affects values and attitudes, but it would make of an interesting research topic.

Conclusions that can be made from the data are limited as the data does not provide further insights on the differences between genders and different fields of studies on their attitudes towards sustainability. It would be interesting to conduct a longitudinal survey study to observe how attitudes towards sustainability develop during studies in different study fields and between genders.

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ISSUES INFLUENCING ASSESSMENT PRACTICES OF INTER-PROGRAM CHALLENGE-BASED LEARNING (CBL) IN ENGINEERING EDUCATION: THE CASE OF ISBEP AT TU/E INNOVATION SPACE

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ABSTRACT

This paper reports on 11 issues influencing the assessment practices of ISBEP, an inter-program Challenge-Based Learning (CBL) project facilitated by TU/e innovation Space. To this end, we first identified four characteristics of inter-program CBL guided by the existing literature. Building on an exploratory, qualitative research study conducted over a period of seven months with students and coaches of the TU/e innovation Space Bachelor End Project (ISBEP), we identified the issues arising from those characteristics that had an influence on assessment. Our results and discussion are framed around the theory of constructive alignment, and suggest the need for more time to navigate a challenge; clarity on roles and expectations across the multiple stakeholders involved in the learning process; agreement on learning goals that foster the development of disciplinary knowledge and broad skills; and design and evaluation of assessment practices that are uniform across departments in the institution.

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1 INTRODUCTION

Challenge-Based Learning (CBL) is an educational concept with ever-growing relevance in engineering education. In CBL, students collaborate to develop solutions to open-ended challenges of societal relevance. CBL is considered a rich learning environment, where engineering students can broaden their professional skills by engaging in interdisciplinary, real-life, multi-stakeholder situations, and by designing solutions to complex problems [1].

CBL is at the core of the education strategy of Eindhoven University of Technology (TU/e), where the goal is to have CBL as the main characteristic of the on-campus education by 2030[2]. CBL has now been explored in several educational experiments at the bachelor and master level. One of these experiments is the innovation Space Bachelor End Projects (ISBEP), an interdisciplinary final project offered to all bachelor students of TU/e.

The novelty of ISBEP is that it is an *inter-program* project offered as an alternative to the 'traditional' Bachelor End Project (BEP). In contrast to a regular BEP, which takes place at and is coordinated by the different departments, ISBEP is conducted in a team and offered and coordinated by TU/e innovation Space (the centre of expertise for CBL and student entrepreneurship a TU/e[3]). As an inter-program CBL project, engineering students from all TU/e departments join to work in *interdisciplinary* teams towards solutions to challenges of societal relevance. These challenges are offered by companies, institutions or university research groups and student teams, which are officially known as challenge owners.

With respect to assessment, students have the same learning goals as established by the departments in relation to their programs, plus an additional set of learning goals related to the context in which ISBEP takes place (i.e. interdisciplinary, challenge-based, of relevance to society). Formative assessment is supported by TU/e innovation Space, on aspects related to interdisciplinarity (e.g. communication and integration of ideas), and by the different departments, on aspects related to the development of projects from a disciplinary perspective. Furthermore, challenge owners provide feedback to students on the relevance of ideas and overall project direction. The final (summative) assessment is individual, and it is led and conducted by each of the departments.

The ISBEP program has been running for three consecutive years. The experiment has been periodically evaluated, and there are continued efforts to improve the educational concepts. Overall, the response from students, staff and challenge owners has been positive. However, reports from practice suggest there are opportunities for improvement, particularly in relation to *assessment*. In an effort to understand the characteristics and issues influencing assessment in inter-program CBL, a research study has been initiated. This paper reports on the finding from the first part of the project, the exploratory study. In this paper we pose the following research question:

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[2] *https://www.tue.nl/en/news/news-overview/03-09-2018-tue-launches-strategy-2030/*
[3] *https://www.tue.nl/en/tue-campus/tue-innovation-space/*

What issues/characteristics of inter-program CBL influence assessment practices?
The remaining paper first offers an overview of the theories framing our research project. In subsequent sections, the methodology is explained, followed by results of our study. We conclude the paper with a discussion on the implications of our research findings for the design of assessment practices.

2 THEORETICAL FRAMEWORK

We use the theory of Constructive Alignment to frame our research. Constructive Alignment (CA) is a student-centred approach to designing education [2]. CA is achieved when teaching/learning activities and assessment are designed to support the achievement of learning outcomes. It has been associated with high quality learning outcomes and student satisfaction (e.g. [2], [3]). Learning experiences should be designed aligning the (1) learning goals, (2) teaching/learning activities and (3) assessment practices, to maximize the intended learning of students. CA has been widely used in higher education and has been reported as a relevant approach in the design of interdisciplinary education [3]. Below we characterize CBL in relation to these three elements, based on preliminary research available on CBL.

2.1 Characteristics of CBL

In relation to *learning activities*, students of CBL are said to frequently engage in multidisciplinary teamwork [1] [4]. Students participate in problem formulation activities; they are presented with general concepts from which they must derive a challenge to work on. Students need to arrive to a specific problem definition by themselves by answering a series of questions, which are called essential questions [5][4]. CBL involves work on real-world problems of societal impact [4] [6]. Projects are typically multi-stakeholder and involve a wider community [1]. Furthermore, students engage in projects that are solution oriented [6]. CBL is a 'learning through doing' approach, where students work towards tangible or experiential solutions, involving prototypes and other manifestations [7].
In relation to *intended learning outcomes*, CBL is said to involve the development of disciplinary knowledge and broad skills [1]. The reported learning outcomes of broad professional skills involve: communication, collaboration and organization, stimulated by working on real-world problems and the interaction with multiple stakeholders [5][1][4] as well as 'identifying, formulating and managing complex problems in a critical, independent and creative manner' [1].
In relation to *assessment practices,* research linking CBL and assessment practices is highly underdeveloped. However, reports from practice, such [7] and [8], suggest formative and summative assessment as being actively used in the CBL context. Formative assessment is highlighted as an important tool to help students develop self-regulating skills for life-long learning [7], which is recurring and guides decision making. CBL is self-directed, for which the role of educators is that of making sure students are on track [5] [6]. Similarly, the role of educators changes from 'dispensing-information' to guiding the construction of knowledge [4] and the process [7].

In regards to summative assessment, [8] emphasize three areas: content knowledge, mastery of real-world skills, and process. Summative and formative assessment tasks are said to be intertwined for CBL and providing clarity to students on what activities constitute a basis for summative assessment is advised [7]. Evidence for summative assessment is described as varying in format, such as reports, final presentations, debates and portfolios [7]. Self-reflection is encouraged and used as part of the assessment[4], [6]. Overall, assessment criteria is described in relation to intended learning outcomes and aligned with the theory on CA previously described.

2.2 Constructive Alignment and Assessment Design for Inter-program CBL

Borrego and Cutler (p. 366) state that "decisions about assessment evidence should be driven by the learning outcomes, and decisions about learning experiences should be guided by helping students develop the ability to provide this evidence" [3]. CA is key for the design of assessment in inter-program education, as intended learning outcomes, learning activities and assessment might be prioritized differently by the departments involved. Lack of alignment in inter-program CBL could lead to important repercussions for assessment and learning of students. Existing literature of CBL has focused on illustrative cases describing the implementation of CBL in higher education (e.g. [9]–[11]), or on highlighting the benefits of CBL when compared to traditional engineering classroom (e.g. [6], [12], [13]). However, implications of inter-program CBL for assessment design have, to our knowledge, not been documented and are key for the further development and upscaling of CBL. In this paper, we investigate this underexplored context by trying to identify the characteristics and issues, which can influence assessment design. Our main goal is to illustrate the intricacies of assessment in inter-program CBL, and contribute to the design and evaluation of similar (well aligned) programs in engineering education.

3 METHODOLOGY

3.1 Data Collection

We followed a longitudinal, exploratory research approach on ISBEP for a period of seven months (from July 2019 through January 2020). Our methods included different qualitative techniques, such as in-depth interviews, contextual inquiry, group interviews, focus groups and observations. Combined, these techniques granted us with rich contextual information to understand the intricacies of ISBEP of relevance to our research goals [14].

Participants

Participants included the different stakeholders involved in ISBEP and were selected to reflect the variety in perspectives of those involved:

Students: Three interdisciplinary teams working on ISBEP projects. Teams were formed by a total of 11 students in the third and final year of their bachelor program.

Departments: Seven academic coaches. The four academic coaches of students participating in the research (some coaches coached multiple students), and five

coaches from a past version of ISBEP. Together these brought the perspective of seven different departments.
TU/e innovation Space: Two TU/e innovation Space coaches.
Challenge Owners: Three Challenge Owners, one for each of the ISBEP projects.
All participants joined the research voluntarily and were informed of the ethical aspects of the research through an Informed Consent Form. No compensation was offered.

Procedures

Our research was executed in two phases: Problem exploration and detailed study of ISBEP.
The goal of phase one was to attain an initial picture of the studied situation. Furthermore, this phase allowed us to fine tune our research questions and design of methods. The problem exploration was completed by carrying out semi-structured in-depth interviews with five academic coaches from five different departments (from a previous version of ISBEP). Phase two focused on the detailed research of a full ISBEP cycle during which several activities were conducted: First, observations [15] combined with contextual enquiry [16] of interactions of students working on the interdisciplinary projects, interactions of student teams and coaches, as well of other learning activities. The goal was to capture the experiences of students and coaches while engaging in learning activities and formative assessment practices. Second, semi-structured, in-depth, group interviews with ISBEP teams [17], and semi-structured, in-depth interviews [18], with (academic) coaches of ISBEP projects at three points in time: at the start of the project (to reflect on early learning experiences, as well as expectations towards formative assessment practices); halfway (to reflect in more detail about the role of coaches and other stakeholders as well as formative assessment practices); and at the end of the project (to capture impressions and experiences towards summative assessment and revisit the overall experience with ISBEP). Third, two focus groups with academic coaches, innovation Space coaches and challenge owners [18]: halfway and at the end of the project (to evaluate learning activities, (formative) assessment, and other aspects, such as the organization/design of ISBEP, which could have an impact on assessment practices).

3.2 Data Processing

All interviews were transcribed verbatim. Atlas.ti was used to analyse the data by using a conventional content analysis approach [18]. A first set of seven interviews and minutes from two focus groups were open-coded by the main researcher, leading to a total of 134 codes. The large set of codes reflected the varying views brought in by the different participants. This set of codes was reviewed by the research team for analysis triangulation [18] leading to the identification of a preliminary set of themes and constructs. Field notes and secondary sources, such as internal reports, were also used for triangulation.

4 RESULTS

We identified four characteristics of Inter-Program CBL and related them to the three elements of constructive alignment as discussed in the theoretical framework. These characteristics led to 11 issues in inter-program CBL (Table 1). The following sections report on the characteristics and respective issues, based on the partial analysis of seven interviews and two focus group interviews.

Table 1. Overview of Results

Elements of Constructive Alignment	Characteristics of Inter-program CBL	Issues in Inter-program CBL	Sample quote from the interviews
Learning activities	Open-ended Challenges	Longer period to navigate the challenge.	*"It takes time to rephrase that into a project for yourself […] the major chunk, maybe even up to four weeks of the start of the project, the students are still like not sure what they're going to do, and the others are full speed ahead." Academic Coach 1.*
	Multi-stakeholder	Managing and balancing the needs of a larger set of stakeholders.	*"Coming from [department], it is quite important that I have both the [discipline-specific content], but also a technical component […] And I managed to send [academic coach] an email about that. And he did confirm that I couldn't neglect it [that] it would be negative on my end grade […] So that has been hard to sort of bring into... with the challenge owners as well." Student 1*
		Maintaining the overview of roles and responsibilities.	*" I'm eventually grading the students and if I tell the student that what [he/she is] doing now is not sufficient from our [department] perspective, that [he/she] should do something different, then who should [take care of it]? Is it her problem? […] should the challenge owner solve it? or there's also someone, like [TU/e innovation Space Coach, who is in fact supervising all the projects for the process?" Academic Coach 4*
		Reduced feeling of accountability.	*"here in my department, if I put forward a proposal, and then a student is assigned to a proposal. And then one day I say I don't want to do this anymore, it's a very bad thing, I would get fired. But that's not the case for ISBEP. And we saw several cases where students sign up for a project, and then the [Challenge Owner] who proposed the project, drop it […]" Academic Coach 3*
Intended learning outcomes	Development of disciplinary knowledge and broad skills.	Balancing individual and team goals.	*"I think everyone is still figuring out how to do their part. And for me, and for [Student 11], we don't really have, like, you have to do this for your faculty […] we all don't really know what to do for our faculty." Student 12 / "I think the projects are nice and okay. But it's difficult for the students to find their own separate topic. Because if I wouldn't have forced them to find their own topic, and to make separate projects in the end, or make separate reports, they would have continued to do this as a group, and work as a group on exactly the same thing all the time." Academic Coach 4*
		Maintaining interdisciplinarity (motivation).	*"I am being unable to concretely define a final product of some kind […] that we can all work on together to achieve. And for me that's been difficult because it was a huge motivator for me to work in a group and to work commonly together towards a goal. And that's why I wanted to do the innovation space BEP." Student 1*
		Achieving enough disciplinary depth (fulfilling assessment criteria).	*"of course, part of the project is the multidisciplinary part and that's an important one, because it's also one of their learning goals […] But they should also come up with something in depth, something where they show that they can do [program] on a bachelor end level. And that's a bit tricky" Academic Coach 3*
		Creating high quality evidence for disciplinary development.	*"I was just really afraid that the quality wasn't a high enough standard for a bachelor university" Student 3*
Assessment Practices	Diversity in rules and regulations	Unclarity about assessment procedures and criteria.	*"I have no idea whether I checked all the, how do you say that, the demands for delivering a proper bachelor's end project" Student 11*
		Discrepancy between perceived learning outcomes and assessment criteria.	*"to me, it...you can't see from the [report] the amount of things that people have learned while doing this. So the learning for the student, I think, is much more valid, because they learn in a much more complex setting" Academic Coach 1 / "Being Challenge-Based has*

			more of a focus on the process. So there should be more indication that it is not about the result that you get in the paper, but that it is about the process" Student 1
		The need to adapt procedures and practices.	*"The way I see is, we either have a joint committee, and these ISBEPs are of a different category. And a separate day in a different building with a mix. So that the assessment committee should reflect the multidisciplinarity aspect of the project. Or these kids do a plus. And then they come to us, and they assessed on the [disciplinary] content. And then they have another forum where they assess on their business" Examiner*

4.1 Learning activities: Open-Ended and Multi-Stakeholder Challenges

One of the main features of inter-program CBL at TU/e innovation Space is that students work on open-ended challenges. These challenges were characteristically ill-defined, i.e. abstract, with no clear set of goals/outcomes, and typically unstructured, with no predefined set of steps of processes to be followed. Having open challenges as a starting point facilitated that students from different programs found a focus within the challenge suited to their respective disciplines. Furthermore, the process and steps to be followed were project-dependent and identified by students themselves. Accordingly, ISBEP students dedicated the first weeks of the project to explore the challenges and identify well-defined problems to focus on. However, this led ISBEP students to need considerably ***longer periods to navigate the challenge***; particularly when compared to the traditional Bachelor End Projects (BEPs), for which the process was sometimes perceived as 'inefficient'.
In accordance with existing literature, inter-program CBL at TU/e innovation Space is multi-stakeholder, but the number of stakeholders surpassed our suppositions. Stakeholders involved TU/e innovation Space coaches and tutors, academic coaches, and challenge owners, who supported the process by providing close feedback on the execution of the project. In addition, ISBEP involved other stakeholders, such as experts, secondary examiners, and assessment committees, which are not formally part of the project but influenced the learning experience/outcomes of students; for example, in setting a direction for the project, in making decisions on project execution, and making resources available.
Importantly, we found that stakeholders varied per student for inter-program CBL, even within the interdisciplinary team. As a consequence, students struggled to ***manage and balance the needs of a larger set of stakeholders***. Inter-program CBL is a new and complex scenario for students, where maintaining the overview of stakeholders and their needs was experienced as demanding.
However, the large number of stakeholders also brought challenges for coaches, challenge owners, and other stakeholders, who struggled *to* ***maintain the overview or roles and responsibilities in the projects.*** For example, there were misunderstandings in relation to project ownership. Similarly, there were questions related to the responsibility for ensuring that students have access to the necessary resources to complete their projects. Moreover, the large number of stakeholders was perceived to ***reduce the feeling of accountability*** of some stakeholders. In the case of ISBEP, commitment from challenge owners and their involvement/continuity in projects, were brought forward as aspects of concern by academic coaches. Overall, misunderstanding on roles and expectations negative influenced the

execution of projects, resulting in delays for students, and compromising the development/depth of their disciplinary knowledge.

4.2 Intended Learning Outcomes: Developing Disciplinary Knowledge and Broad Skills

Inter-program CBL at TU/e innovation Space supports the development of disciplinary knowledge and broad professional skills. ISBEP students were encouraged to define individual and team development goals. To support the setting of individual goals related to their personal and professional development, TU/e innovation Space set up activities via a Learning Management System (LMS), which students engaged in periodically. Activities contained questions that were meant to stimulate students' self-regulated learning; to help them monitor their progress in relation to their goals, and to reflect on/adapt their learning strategies. Its goal was to support reflections by students when meeting their academic coaches, who would simultaneously encourage students to think of learning goals, from a disciplinary perspective.

At the same time, teams were encouraged to define team goals for the interdisciplinary project, which was supported by TU/e innovation Space through weekly coaching meetings and encouraged through 'mid-term' presentations involving the key stakeholders. At these presentations students were actively asked about their envisioned end-results, as well as the integration of individual contributions. Consequently, students had to find a ***balance between individual and team development***, which was not easily achieved. The pull between the two was constant throughout the projects, and was felt as intense by students and coaches alike, albeit the consequence of not achieving this balance varied. For students who centred too much on their disciplinary development, ***maintaining the interdisciplinarity of the project*** was difficult, while interdisciplinary work was an important motivator, and a key reason for students to join ISBEP. When interdisciplinarity was lost, students failed to see the value of ISBEP, compared to regular bachelor end projects. For students who centred too much on interdisciplinary work**, *achieving enough depth in the disciplinary (individual) projects*** was a testing, as well as ***providing high quality evidence for their disciplinary development.*** This could be attributed to problem definitions promoting interdisciplinarity, which then sometimes fell out of departmental expertise. As such, students struggled to determine the relevance of information related to their projects and some academic coaches struggled to guide students on the disciplinary content, and to connect them to relevant experts.

4.3 Assessment *Practices:* Diversity in rules and regulations

Inter-program CBL at TU/e innovation Space was characterized by a large diversity in rules and regulations due to the internal policies of the different participating departments. This diversity brought about different issues. First, there *was **unclarity among students about assessment procedures and criteria***. For participants in this research, the fact that they were assessed following the criteria of regular BEPs

was particularly confusing (as they expected ISBEP specific criteria). Moreover, students expected part of the summative assessment to be conducted by TU/e innovation Space coaches and challenge owners. Students were often surprised to find out that summative assessment was mainly conducted following a disciplinary perspective and led by academic coaches and other members of the specific programs. Second, there was a perceived ***discrepancy between the learning outcomes of students and the criteria by which they are evaluated.*** A large portion of learning activities and perceived learning outcomes related to team/interdisciplinary work. Consequently, students expected (part of) the summative assessment to be related to the learning outcomes associated with this. Third, some academic coaches expressed the ***need to adapt procedures and practices*** to this new context of inter-program CBL. Academic coaches needed to familiarize themselves with ISBEP, its learning activities and expected outcomes. Some coaches perceived the departmental assessment practices as not fitting (i.e., not well aligned) with ISBEP. For example, having to create flexibility in the current procedures, or including additional steps, to provide students with a fair assessment.

5 IMPLICATIONS FOR ASSESSMENT

In the case of inter-program CBL, constructive alignment (or lack thereof) appeared to be particularly influenced by the **larger number of stakeholders** taking part in the projects, and their varying perspectives. At the level of *learning activities*, the impact of a larger set of stakeholders was well reflected in the difficulty to maintain an overview of roles and responsibilities of those involved facilitating learning. In terms of *learning outcomes*, the varying and unaligned expectations of stakeholders influenced the attainment of learning goals. And at the level of *assessment practices*, the larger number of stakeholders brought about varying departmental assessment procedures and criteria, which created uncertainty. **Diversity in rules and regulations** also proved to be an important barrier in the delivery of a significant learning experience to students. In this regard, Fink proposes a model for institutional effectiveness [19], and positions rules and regulations as an important element in promoting/blocking the implementation of effective learning–one in which learning goals, learning activities and assessment practices are well integrated (i.e. well aligned). Furthermore, in discussing constructive alignment across the institution, Biggs and Tang describe teaching as a multi-layered ecosystem [2]. Under this perspective, modules and their design are teacher dependent, and influenced by departmental rules and regulations, which are in turn influenced by institutional policies in education. Thus, for inter-program CBL to be successful, there has to be an important focus in aligning learning goals, learning activities and assessment practices–and regulations–across departments, but also between department and the intuitional vision on education.

Achieving this **alignment across the institution** can potentially address several of the reported issues in terms of: more clarity on roles and expectations across stakeholders; agreeing on learning goals that foster the development of disciplinary knowledge and broad skills; and designing and implementing assessment practices

that are uniform across departments, student-centred, and promoting the attainment of learning goals. To achieve such clarity, Evans proposes several tactics for reaching assessment literacy [20] which in the case of ISBEP, would imply directing efforts at increasing the clarity regarding the roles of stakeholders, by making their roles, expertise, and what/when students can reach out to them for more explicit feedback/coaching. Finally, in designing well aligned interdisciplinary learning experiences, Borrego and Cutler advice seeking involving multiple sources [3] to reach agreement across programs on the expected learning outcomes of this type of education, and at this educational level. In conclusion, constructive alignment might not be easily attainable in the context of in inter-program CBL, but is key to promote the design and implementation of student-centred assessment practices (and learning activities), which promote the achievement of learning goals [2], [21].

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GET READY FOR A SMART WORLD: STUDENT'S VIEWS ON FUTURE-PROOF EDUCATION

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ABSTRACT

One of the tasks for higher education is to prepare students for their role in a changing world and to stimulate them to develop broader competencies than only in their own discipline. There are many initiatives in which existing curricula are redesigned to prepare students for this changing world. These new curricula oftentimes contain hybrid learning configurations, in which theory and (authentic) practice are intertwined, such as in project-led education, innovation labs, or workplace learning. But what are -according to students- key ingredients of future-proof education?

Within Saxion University of Applied Sciences in the Netherlands, an explorative, qualitative study was conducted amongst 74 bachelor students from >20 programs, including technology and engineering programs, such as mechatronics, industrial design, or biomedical engineering. Focus group interviews were held with 24 groups, of different group sizes from 2-7 students. Interviews started with the question: What are -according to you- key ingredients of future-proof education? The interviewers directly during the interview coded the reported ingredients deductively, following a prespecified scheme based on literature. New themes were added inductively, when necessary. Next, interviewers prompted on the first answers, asking for clarification or examples.

The report follows the outline of the adapted coding scheme. Distinction was made between 1st/2nd year students versus 3th/4th year students since the latter provided more in-depth and experience-based information. According to students, main ingredients of future-proof education are: authentic projects (mentioned in 22 out of 24 groups), blended/online learning (16), self-directed learning (15), teacher as coach (15), active learning (13) and collaborative learning (11). Results were used

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as input for the formulation of a new educational vision and Education Model, specifying ingredients for our future education.

1 INTRODUCTION

Working in the future labour market requires new skills from current and future engineers and, consequently, new curricula to help them require these skills. Recently, the executive agency for small and medium-sized enterprises, EASME, published a report [1] in which they present a framework and guidelines for vocational education of how to develop and implement curricula focused on these skills. Based on market and labour market developments, the agency concludes on p.13 that having knowledge or technical skills is not sufficient anymore. Instead, employees need to have the "…*ability to adapt to continuously changing circumstances and to constantly advance one's knowledge and skills. Focussing on technical skills only is thus not enough. Other crucial non-technical skills refer, among others, to critical thinking, creativity, communication skills and ability to work in teams*". This places demands on the education programmes that prepare students for this labour market. With others, EASME pleads to centre education programmes around real-world experience and real challenges, and to create possibilities for real-world application of skills in the curricula, through close collaboration of business and educational institutions.

It is logical that higher (vocational) education uses such analyses of requirements within the labour market as a starting point for designing curricula. Many curriculum innovation initiatives encompass the creation of learning environments, in which school-based learning and work-place learning are intertwined [2]. Some examples are project-led education [3], or innovation labs [4]. Interestingly, the views of students, as future learners in those curricula, often remain underexposed. To what extent do these curriculum innovation initiatives connect to students' views of future learning, and connect to their preferences? *What* do students want to learn, and especially, *how* do they want to learn? As a first step in an institution-wide curriculum redesign process at Saxion, this question was asked to several groups of students in focus-group interviews.

2 LITERATURE

Preceding the focus group interviews with students, the researchers carried out a small literature study, in which they searched for current trends in literature on curriculum innovation. Because of the explorative nature of the full research study, the literature study was explorative too. The researchers regarded the exploration as an expedient to help them analyse students' answers more quickly to detect evident differences, e.g. themes portrayed in the literature but not by students, or vice versa. The themes in the literature study relate to *what* to learn as well as to *how* to learn.

What to learn

In various articles and reports [e.g. 1, 5], there is attention to the balance between knowledge and skills in future jobs and, accordingly, in future-oriented education. Whereas professional knowledge remains important, studies also show that the labor market increasingly asks for skilled employees, beyond mere technical and specialist skills. These skills are often referred to as *key skills*, *lifelong learning competencies*, or -usually in education- as *21st century skills*. Although there is no uniform overview, several of the following skills are mentioned frequently: collaboration, ICT skills, communication, social skills, creative thinking, critical thinking and problem-solving skills [5]. Recent research [6] also shows that employers see collaboration, adaptability, and skills for personal development as important competences for the employee of the future. These skills build up to their professional identity. In one's professional identity, knowledge, skills and attitude come together, and one's own identity becomes visible in relation to peers, to other professionals outside the discipline, and to the wider society. There is a task for education to help students learn to understand themselves, and to make good choices, for example, aimed at further development of their professional identity. Self-driven learning and reflection skills, as well as a focus on personal development are crucial in this.
For our interviews, we selected the themes: role of knowledge, role of 21st century skills, reflective skills, personal development, self-driven learning, interdisciplinarity.

How to learn

It is generally known that teachers can use several teaching strategies that invites students to engage actively in learning during class time. This is referred to as 'active learning' [e.g. 7]. Such teaching strategies can comprise of small or larger cognitive challenges or practical exercises. Examples are interactive Q&A-sessions, or working on cases, in which a problem of industry is being modelled in class. Beyond active learning, there is a major movement in higher education to create learning situations in which practice is not only modelled but becomes the core context of learning [2]. When learning situations represent the work situation, this fosters authentic work-based experiences, which helps students learn how to deal with the full complexity of their future work [2]. Projects can offer students such an authentic context [3] in which they can acquire, apply and deepen practice-relevant knowledge and 21st-century skills. By working on projects, students learn from and with each other. During this process of collaborative learning, students construct and develop collective meaning [8]. This is something that is also becoming increasingly important in professional practice, where work is based on interprofessional expertise and the joint creation of knowledge. By introducing collaborative learning into education, the necessary skills required by professional practice can be stimulated [9].

One way of fostering (collaborative) learning within education programs is in terms of the creation of a community of learners. By coming into contact within this community with different people, their preferences, opinions, knowledge, behaviour, etc., the learner has access to more different sources than the instructor alone and,

therefore, to potentially more learning opportunities [10]. Such communities of learners are effective because they lead to social bonding between students and between students and instructors. Being able to work on assignments from professional practice within the community has a positive influence on both student motivation and the learning process [10].

Within the 'new' forms of education, the role of the teacher is often compared to that of a coach. In this role, teachers are expected to create a safe and motivating learning environment and on the other hand to apply coaching activities focused on the learning process. This can be divided into three overarching categories of coaching activities, namely asking questions, giving feedback and offering support [11]. Teachers have a crucial role in creating an atmosphere where students feel comfortable and safe to answer questions, share their images, discuss, make mistakes and fix them. This ultimately contributes to the quality of learning [12].

One final theme, which is permeating education relates to the use of technology. This creates the possibility to move parts of the instruction outside the classroom -online, through video clips, etc.- and to work on elaboration and practice during class. Concepts such as blended learning, flipped classroom, online learning, e-learning, are just a few connected terms, that all relate to a certain combination of online and offline learning. We use the umbrella term 'blended learning'.
Relatedly, we see a trend moving towards more flexibility for students, not only aimed at pace, place and speed of learning, but also on what they lean. Institutions think about individual learning paths. Through the application of technology, these possibilities come into reach.
For our interviews, we selected the themes: authentic projects, active learning, blended learning, collaborative learning, learning in (interdisciplinary) communities, teacher as coach, flexible learning.

3 METHODOLOGY

3.1 Context and research question

Saxion University of Applied Sciences currently hosts 56 fulltime bachelor programs (see table 1) and 14 master programs, clustered in 12 schools. 22 part-time equivalent programs are clustered in a separate Saxion Parttime School (SPS). 22 of the 56 programs have a technological and engineering orientation. In total, there are close to 27.000 students. Whereas three schools specialize in technological and engineering programs, all other programs also explicitly connect to technology, since 'Living Technology' is one of the strategic foci of the institution.

Since summer 2018, Saxion is implementing a new educational vision, which is closely connected to recent theoretical insights, promising practices within the institution and viewpoints of teachers and students. In line with the strategic focus of Saxion, the new vision should also encompass a major focus on technology within all the programs.

Within this context, the reported explorative study was conducted, gathering viewpoints from students. The research question that stood central in this study is: What are -according to students- key ingredients of future-proof education?

3.2 Respondents

Data were collected by five researchers, within a time frame of 2 weeks. In order to make sure that all faculties were represented, every researcher was assigned two or three faculties. They agreed to interview at least one student group from each faculty, and at least two student groups from the larger faculties.

Students were approached randomly by the researcher during a lesson break, participation was voluntary. Ultimately, 74 bachelor students were interviewed, from over 20 programs, spread over the four years of studies. One-third (n=24) of these students specifically came from engineering programmes. Focus group interviews were held with 24 groups of students, group sizes ranging from 2 to 7 students. Most groups consisted of 2-4 students. There is a fairly good spread over the four years:
1st year: 6 groups (20 students)
2nd year: 6 groups (15 students)
3rd year: 7 groups (20 students)
4th year: 5 groups (19 students)

3.3 Data collection and analysis

All focus-group interviews started with the question: 'What do you think future education will look like?' During the reporting, these were classified by the interviewer into the predefined categories (themes), derived from literature. Next, probing questions were asked about the various reported ingredients. Students were also asked for examples within the current study program to illustrate their views. Finally, students were asked what they see as the main challenge to get the education of the future realized within our institution. Each interview lasted between 5 and 20 minutes, depending on the group size and on what students had to report. Per interview, the interviewer directly coded the reported ingredients deductively, following the prespecified scheme. The category 'other' was used for new, upcoming remarks. Everything students reported was included. Note that if ingredients were not mentioned, this does not automatically mean that students do not regard these as non-important, merely that these were not on top of their minds.

First step in the analysis was the rereading of all interview reports. It became clear that the older students provided a *more in-depth* view than the younger students, though did not necessarily report more themes. For this reason, during analysis, clusters were made of the 1st/2nd year students on the one hand ('younger students') and 3rd/4th years on the other ('senior students').

As a second step, we summarized all data in one *descriptive data matrix* [13, p.240], ordered by theme, and used this as a basis for the description of results. We looked at how often certain themes came up in the interviews, specified per year (see Table 2), and also specifically searched for any contradictions that arose.

4 RESULTS

4.1 General results

Table 1 provides an overview of how often the different themes were put forward by the various student groups. Themes reported most often, marked with an '*', are working with authentic projects (22), blended learning (16), Self-Driven Learning (15), teacher as coach (15), active learning (13), collaborative learning (11).
Due to the text restriction for this paper, unfortunately, we cannot present all data. Therefore, below, we will highlight these most often reported themes, which came across in both technical/engineering and non-engineering programmes. Sometimes, the general scope of reasoning is illustrated or completed by an exemplary quote from one of the students.

Table 1. Frequencies of themes as topic in the interviews

Theme: *what to learn*	Year 1+2	Year 3+4	Total	***Theme: how to learn***	Year 1+2	Year 3+4	Total
Role of knowledge	5	3	8	Active learning *	5	8	13
Role of 21st skills	0	1	1	Authentic projects*	12	10	22
Reflection	0	4	4	Collaborative learning *	5	6	11
Personal development	5	3	8	Learning in communities	5	3	8
Self-Driven Learning *	7	8	15	Teacher as coach *	7	8	15
Interdisciplinarity	3	6	9	Blended learning *	8	8	16
				Flexibility	4	6	10
				Other	3	6	9

4.2 Most often reported themes

Without using the specific word 'authentic', almost all groups see the relevance of working on **authentic projects** and expect this to increase in future education. In this respect, interdisciplinary work is regarded as important by 9 groups of students.

Overall, younger students foresee a clear link between theory and practice, so that *"one can clearly see what he is being trained for and can more easily choose where he wants to work*". They suppose that lessons will have a focus on application of skills and feedback. Students consider the importance of professional practice as a motivational driver: "*You will do your best for a real client*". Some students even expect learning to take place outside school, in the workplace. In general, they hope to find a good balance between freedom to choose projects and activities of their liking, and structure.

The senior students expect programs to be always up to date with trends and developments in the professional field. They expect more and larger, practice-oriented projects, and they find these more relevant and motivating than small assignments or regular lessons. They expect projects to steer their lessons. As one group puts it: "*In the education programs of the future, more attention is being paid to soft skills, but they are offered only at moments when you really need them. So, no separate course about communication, but offered in workshops, when you are actually going to use it. … The question becomes whether courses will be necessary at all and whether working from books with problems is not very old-fashioned. Only when you start working in practice, school assignments will start making sense to*

you". Several student groups expect to be able to work solely on professional products, with the support of a teacher as coach. One group would regret that: They hope for a good variety between projects and lectures and that "*there will not only be projects".*

Another clear trend is an expected increased focus on **online learning** activities, enabled by technology. Younger students expect more self-study activities through the computer and e-coaching, and stress that for this purpose good ICT skills are essential. Senior students foresee the use of technology for knowledge acquisition, but also to elicit interactive participation in lesson settings. They also think it will become easier to learn in a personalized way, e.g. to make one's own choices, and that the starting point for education will be the qualities of the individual student that he/she wants to develop. They, thus foresee more personalised learning paths, enabled by technology. At the same time, some students do not feel the need for *full* personalization. Neither do they prefer online education above blended learning. They see the value of Virtual Reality as a way of bringing practice into school, enabling students to practice skills as if it were just real. Some students expect online tests to replace paper and pencil tests, since "*After all, there is hardly any writing in the office anymore*".

In general, in all years, students like to be in control of *what* they learn and *how* they will learn, and they also want good support from their teachers. In this context, the relevance of study career guidance was mentioned. A number of students see this as an important component within future-oriented education. A condition for this is that it is clear what choices can be made and what room students are given. It is striking that students see it as a task of the study programme to make the various options visible and see themselves less of a pioneer. In other words: 'I would like to be **self-directed**, but this is only possible when the frameworks within which this can be done are clear'.

Several younger and senior student groups emphasize the importance of personal contact, e.g. learning with peers, working in groups, and meeting with teachers. Moreover, younger students more often than older students seem to express an explicit need for good **teacher coaching** and guidance. This teacher guidance can be focused on, for example, stimulating the process of collaboration in a project setting, on motivating for learning or on encouraging self-directed learning. These students also expect coaching on making good choices, for example during the selection of assignments or (optional) subjects, and in determining what is a good test moment. Younger students portray teachers primarily as transmitters of knowledge, but at the same time do not find this a very motivating function. They rather prefer a short instruction from their teacher after which they can start to practice and experience themselves. Younger students also mention the need for feedback on assignments which they currently, according to them, do not always get from their teachers.

5 DISCUSSION

This small, explorative study was conducted as a first step in an institution-wide curriculum redesign process at Saxion University of Applied Sciences in the Netherlands. In focus group interviews, we asked 24 groups of students 'What are - according to you- key ingredients of future-proof education?'
Although participation was voluntary, the researchers trust that the students interviewed are representative of the population, regarding gender and race. The students were approached randomly, and they all agreed to participate. They covered one-third of all programs and came from all faculties, also reflecting the specific 'culture' of the faculties. Despite this assumption, the results should be interpreted with care, also because of the small number of students involved.

In the focus group interviews with students, it became clear that students somehow associate all the prespecified themes with future-proof education. The interviewed students do not have major differing views, compared to what was put forward in reports and studies [e.g.1,6]. In this paragraph, we will discuss the findings, and share some observations of the researchers, also based on non-reported results. In this respect we hope to be able to give the reader a wider view on the data, than could be presented within the limited number of pages of this paper.

Students' views are coloured by current experiences
The phase in which students currently enjoy education seems to partly colour their views. For example, where younger students reported that the development of professional identity is important, they were not yet able to properly describe the consequences for education. Another example is that the importance of exchanging different perspectives from different disciplines (interdisciplinary education) was mentioned more often by senior students, who were just undertaking interdisciplinary courses in the latter years of their program, such as in the Smart Solutions Semester.

Senior students provide a more in-depth view than younger students
Overall, the younger students seem to find it more difficult to make 'education of the future' explicit than senior students. They seem to put a stronger focus on the structure of the programme. For us, while designing our future-proof education, it is relevant to consider whether this focus on structure stems from the students' own intrinsic need for structure, or whether it is mainly a reflection of the current state of their study programme, indecisive of how future-proof the study programme is. It is, therefore, important to first determine the ingredients of future-oriented education in itself (what needs to be learned), and next, to elaborate those in such a way that they address the learning needs of students, since this is necessary for their motivation and for supporting their learning process.

Theory and practice should be intertwined, authentic projects will to be core
The researchers got the impression that, in their answers, students sometimes seemed to mix up their *views* of education of the future and their personal *needs* of what they would like to see portrayed in their programme. Having said that, almost all groups mentioned the importance of having a continuous alternation between theory and practice. Almost all groups reported the necessity of working on authentic projects and expected this to increase in the future. Interdisciplinary work was also mentioned as important by a number of students. This provides strong support for the current curriculum innovation initiatives in higher education institutions [2,3,4].

Projects provide contexts for collaborative learning (as process and outcome)
In line with literature [9], students regard collaborative learning as an important skill for the future. It is, therefore, important that this is addressed explicitly in the study programme. Collaborative learning can take shape pre-eminently within projects contexts. Here, students make high demands on the coaching of their teachers. They expect support, for example in the form of feedback on the collaboration or reflection on personal development. The fact that some student groups also reported that they do not always get frequent or adequate feedback from their teachers deserves attention. Is this something that holds for more students? Is it due to practical obstacles such as available time, is the importance not recognised, or are some teachers insufficiently skilled in providing adequate feedback, and should this be trained?

Students want to steer their learning process ánd find this difficult
Whereas employers are in need of employees who are able to steer their own development [6], the theme of self-directed learning needs more attention and elaboration during curriculum innovation and implementation. Whereas students do stress their wishes to take responsibility for choices, they expect the programme to spread out exactly their options and choices, thus diminishing the amount of their own control. Where this seems natural for younger students, we would expect senior students to able to set their own goals and take more control. It seems to be important to have teachers who are capable of supporting this self-directed learning process and who can help students develop these skills. It might also be realistic to acknowledge that it is already a good start if graduating students, who just enter the labor market, have developed self-*regulating* skills, and realize that they will further develop a self-*driven* attitude during their career.

Not every student likes online learning
The theme that seemed to get most opposite views was blended learning. Whereas this theme came across in two-third of the student groups, when addressing the opportunities of technology to create online learning situations, some students were not so positive. At most, they value a blend between online learning activities and face-to-face activities, but they would regret a move towards online education. Since the interviews were held in the pre-Corona era, it would be interesting to find out

whether the current enforced online learning experiences during Corona have made them change their minds.

Especially regarding the theme of blended learning, it is important to note that students interviewed were all students who were physically present to enjoy face-to-face education. There is a small chance that this approach has prevented students from participating who stayed away and who might have a preference for online learning.

During the interviews, most students stressed the importance of the coaching role of the teacher, and the necessity to learn together with other students, in communities. Although coaching and collaborative learning could be supported online as well, programmes need to deliberate on good blends of online and face-to-face activities. In either way, there should be a good structure of supervision by instructors, or more flexible choices regarding how students want to learn.

To conclude, the views of the interviewed students on ingredients of future-proof education are mainly in line with the developments mentioned in literature and initiatives in higher education. Their answers provide insight into their needs. It was difficult to distinguish the role of the teacher as a separate theme. It seemed connected to all other themes. From a students' perspective, the teacher is and remains crucial in future-proof education.

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APPLICATION OF VIRTUAL REALITY TECHNOLOGY IN MOBILE WORK MACHINE ENGINEERING EDUCATION

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Keywords*: Engineering education research, educational technology, virtual reality, mobile work machines*

ABSTRACT

The connection between a high motivation to study and a positive learning outcomes is generally known. In engineering education, authentic learning environments have been found to be one of the most important factors to increase students' motivation to study. However, working with a real artefact is not always possible.

A promising method for the creation of authentic learning environments is the use of virtual reality (VR). One VR environment has been developed to study the structures of forest machine crane and harvester head. The purpose of this article is to describe the practicality of this VR environment in engineering education. We focus on the following research question: How do students experience the VR learning environment?

The ongoing research project will be conducted with mechanical engineering students throughout three academic years. Thus far, the obtained results indicate that the students experience increased meaningfulness when learning in a VR environment. However, integrating VR technology into courses is not an easy task. At this point of research, the learning outcomes has not yet been measured. The results of the study will contribute to the development of the VR environment and further research by comparing the learning outcomes of the real and VR environments in a more detailed research framework.

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1 INTRODUCTION

A new generation of engineering students equipped with good information technology skills is embarking on university studies. They have high expectations that their institutions will use modern methods to teach them working-life skills, which they will need in their future work environments. During studies, we often hear students complaining that their education is not modern enough, not practical enough and not interesting enough. We also hear professors complaining that students have little motivation to learn. These challenges require universities to develop their teaching and embrace the use of new technologies.

The implementation of new teaching and learning technologies does not happen overnight. In connection with the introduction of new technologies, teachers' design skills are challenged. However, although they present more possibilities, advanced teaching technologies also present many challenges, and integrating information and communications technology (ICT) into classroom practices continues to be a challenging task for many teachers [1]. To address these challenges, technological pedagogical and content knowledge (TPACK) is a relatively recently developed theoretical framework designed to guide research in teachers' use of ICT [2]. The question also easily arises as to whether the additional work required for the introduction of technology is worth the effort. Factors influencing student motivation to learn can be outlined using many theories [3]. In the context of this study, perspectives of the self-determination theory [4] have been utilized.

VR has been in use in certain skill learning apllications for some time. For instance, flight simulators and also driving simulators are in wide use. Currently, VR has been applied also in engineering education, training and research [5]. Technology enables an authentic experience and combines students' abilities to use modern information technology with the needs of teachers to create motivating learning environments [6]. The hypothesis of this study is that VR learning environments are also well suited for a mobile work machine engineering education.

One particular VR environment has been developed to study the structures of forest machine crane and harvester head. The purpose of this article is to describe the practicality of this VR environment in mobile work machine engineering education. We focus on the following research question: How do students experience the VR learning environment as part of their engineering education?

The following is structured as follows: Section 2 discusses the research method used, focusing on the research strategy and data sources. Section 3 introduces the results of the research. Section 4 discusses the findings of the study. Finally, Section 5 concludes the paper with future directions and final remarks.

2 METHODOLOGY

One key area of research related to teaching and learning that has recently gained attention is the study of technology-based interventions to increase learning motivation. Research can be carried out by many different methods. The research described in this article is the first in a series of interventions aimed at improving the learning process through a VR learning environment. The research will be conducted using the educational design research (EDR) method. The strength of this method can be demonstrated by the ability to carry out carefully planned scientific research while simultaneously producing solutions to problems arising in practical teaching tasks [7]. EDR is well suited for research like this because it is characterized by an iterative structure. In EDR, new knowledge and interventions evolve over time through several stages of research, development and testing [8]. This paper describes the first cycle of research. EDR also allows the combination of different forms of data collection.

2.1 Description of the learning task

The suitability of the VR environment for engineering education was studied in connection with normal teaching in the academic year of 2019-2020. The learning task was included in connection with laboratory courses in automotive and work machine technology. In laboratory courses, students were divided into groups of a few students who do one learning task per teaching session. The duration of the teaching session was three lessons. Thus, the students worked continuously for about 2.5 hours.

Sixteen groups completed the learning task during the school year. Six groups were in their fourth year of engineering studies, eight groups were in their second year, and four groups were exchange students from different countries with different levels of studies. All the students of classes participated in the research. A total of 69 students completed the learning task. Most often, the group size was four students, but configurations of three and five students were also used. With this number of participants, a sufficient amount of data was accumulated to form a reliable overall picture.

The aim of the learning task was to learn the structure and operation of a forest machine crane and a harvester head by dismantling both structures part by part in VR environment. After completing the assignment, the student should be able to name the main components of the assemblies and explain their functions and operating principles. The learning task began under the guidance of a teacher, where the configuration of the VR equipment was reviewed. Next, the equipment was commissioned, i.e. the necessary connections and calibrations were made. After these steps, the user interface and functionalities of the program were further reviewed under the guidance of a teacher. After this, the teacher left the room and the students were began using the VR environment on their own. If problems or a

need for guidance arose during the work, students were instructed to report to the teacher working in the adjacent space.

Because only one VR hardware was available, one student at a time was able to use the virtual environment. The group decided on the length of an individual student's VR period and changed the user of the equipment at appropriate intervals. Other members of the group were able to follow the events in the VR environment through an image projected on the screen. At the same time, they wrote down answers to technical questions, took care of wires and other hazards to the user and guided the student using the equipment based on the screen image.

2.2 Data collection

In connection with the assignment, the group was given a form that included questions about the structure of the crane and harvester head. Students were required to fill out this form together during the assignment. In addition, each student received a personal feedback form related to the VR environment to complete after the learning task. They were also told about the group interview that would take place in connection with the return of the forms. The interview was conducted in a semi-structured format, leaving students with the opportunity to share their experiences also freely.

The purpose of the personal feedback form was to obtain information on how each student experienced the use of the VR environment as part of their engineering education. Students rated the excitement, meaningfulness, immersion in the task and quality of learning. In addition, they evaluated the functionality of the technical implementation in its various areas. The aim was also to find out how they experienced the environment physically, i.e. whether the work caused nausea or other unpleasant feelings. Students were asked to state on a 5-point Likert scale to what extend they agreed or disagreed with the statements. There was also additional questions, which were open in nature, allowing students to express their opinions freely.

In the group discussion at the end of the work, the teacher was given the opportunity to evaluate the students’ learning by asking more specific technical questions. The discussion was conducted on the basis of pre-prepared questions that were repeated in each discussion. During the conversation, the teacher got a good overall picture of the students' attitudes toward a new type of learning assignment. The forms and the group discussions thus resulted in both quantitative and qualitative data for analysis.

2.3 Data analysis

To get accurate results from the research questions, the collected data was carefully analyzed. The forms were reviewed by the research team. The numerical evaluations provided by the students were recorded in Excel software to enable

statistical analysis. The answers to the open-ended questions were analyzed together in group discussions. During the discussions, answers were categorized and key findings were recorded. The notes collected during the group interviews with students were also analyzed and the main findings were recorded. Teachers' experiences of using the VR environment as part of their teaching were mirrored in the TPAC framework. Student responses were analyzed in an effort to identify motivational factors in the context of the self-determination theory. The physical effects caused by the VR environment were compared with the results of previous studies.

3 RESULTS

The aim of the study was to obtain information about the usability of the VR learning environment from the perspective of the student. At the beginning of the feedback form, students were asked to compare VR study with traditional classroom instruction on a scale of 1-5. On the scale, a grade of '1' indicated that the student felt that classroom instruction was far superior, while a grade of '5' indicated that the student felt that VR learning was a better option. With a grade of '3', the environments were perceived to be on an equal footing. The following are statistical results supplemented by the answers from open-ended questions. The stage of studies (second or fourth year of engineering student) did not cause significant differences in results.

In general, students felt that the VR environment was a more inspiring environment than the classroom (Q1 average score: 4.6). Immersion in studying was also at a good level (Q2 average score: 4.0), but more students reported that the environment attracts extra gimmicks, which reduced the focus on studying. The meaningfulness of the learning task was perceived as high (Q3 average score: 4.5). The quality of learning was considered somewhat better than the classroom (Q4 average score: 3.7). Although the environment itself did not require the presence of a teacher to function properly, several students did perceive the absence of the teacher as a problem. This was primarily due to questions raised during the work, for which the students were unable to receive answers immediately. Figure 1 shows a comparison with traditional classroom instruction, including standard deviation.

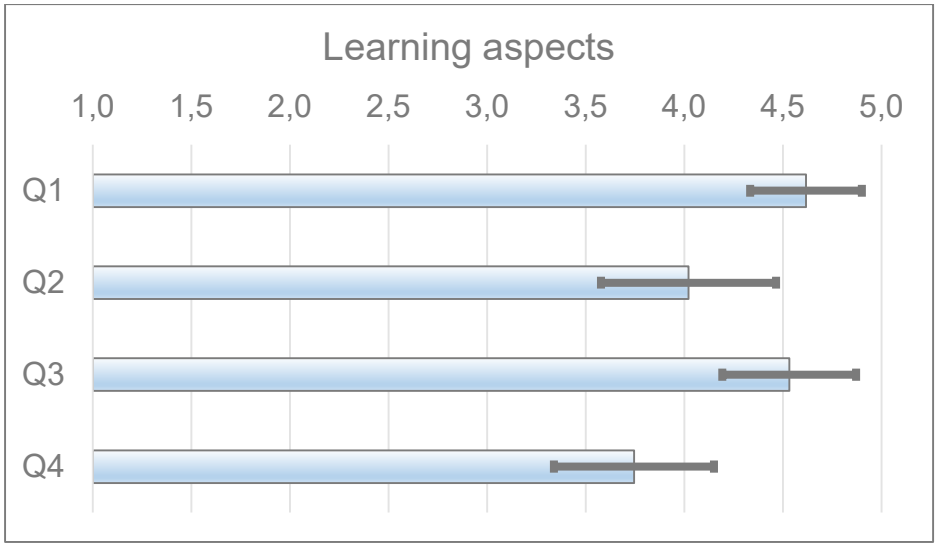

Figure 1. VR learning environment comparison with traditional classroom instruction.

1= classroom is superior, 3=equal footing, 5=VR is superior.

Issues related to the technical implementation of the environment were also assessed numerically on a scale of 1-5. A rating of '1' meant poor technical implementation, while a rating of '5' meant excellent. The classroom as a space was considered to be functional for the use of equipment (Q5 average score: 3.9), although some students wanted more space, allowing for greater possibilities to move during the work. At the same time, the cable for VR glasses was found to restrict movement and even pose a danger if operated alone.

The usability of the VR environment was considered good (Q6 average score: 4.1), indicating that the factors affecting the smooth operation (e.g. the menus, the logic of the functions, etc.) were at a good level. The functionality of the program, on the other hand, received a slightly lower rating than the usability (Q7 average score: 3.7.) This was mainly due to the limited performance of the computer's video card and the resulting momentary image jitter. The veracity of the environment was assessed as good (Q8 average score: 3.8). Figure 2 shows the evaluation of the technical implementation, including standard deviation.

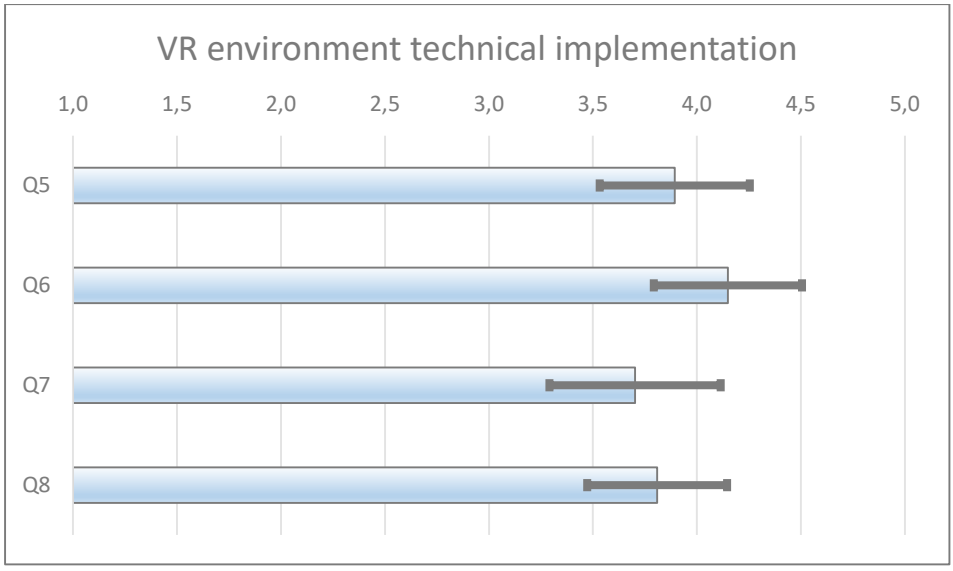

Figure 2. Evaluation of the VR environment technical implementation. 1=poor, 5= excellent

Students rated the physical suitability of the environment for them on a scale of 1-5. A rating of '1' meant that they were only able to use the equipment for a short time due to physical problems. A rating of '5' meant that they felt completely normal throughout the work. In general, students felt that the use of the VR environment was physically suitable for them (Q9 average score: 4.3, standard deviation: 0,32). Many students reported mild physical problems while using the equipment. The most common symptom was sweating, which was mentioned by five students. Other physical symptoms reported included nausea, headache, dizziness, eye fatigue and a feeling of pressure on the face caused by device glasses. In total, 43% of students report some of these feelings. However, the symptoms were generally felt to be mild and did not prevent anyone from using the equipment.

Disadvantages were also found. Some students felt that their group caused a feeling of urgency, which made it impossible to study at their own pace. For some, watching the events from the sidelines caused frustration. There was also room for improvement in the application. Now the program only allows disassembly, not the re-installation of parts. This was considered a shortcoming. Another perceived shortcoming was the lack of gamification. At the end of the exercise, for example, the students needed the opportunity to test their skills and thereby receive feedback. This could have been accomplished through gamification; a competition between groups (which was hoped for) which would have motivated even more effective study.

When asked whether VR teaching should be increased, 92,8% of students answered yes, 5,8% were unsure of their opinion and only one student (representing 1,4%) answered in the negative way. The positive answers were justified in various ways, e.g. an increased motivation to study because the method is inspiring and different. A few students appreciated learning the basics using traditional methods and

suggested that the VR method would be most effective when supplementary and should not be used as a substitute for other teaching methods. Problems related to nausea and other physical symptoms also emerged when considering the increased use of VR environments. The possibility of making one's own video recordings during VR studies also emerged as a developmental proposal, in which case the contents could be returned later if necessary.

4 DISCUSSION

Question of motivation is familiar to every student. Motivation to learn stems from many factors. The self-determination theory suggests that people have a need to do things independently and they want to do things that they find enjoyable [9]. The results of this study support the effect of this premise on study motivation. The VR environment allows events to be managed at your own pace. An appreciation of this was reflected in the high ratings of the meaningfulness of the learning task.

Another premise of self-determination theory is the human need for relatedness [9]. This type of exercise can be done as groupwork. This can be seen as a strength because then students can discuss the project and reflect on technical issues together. The feeling of competence is also one of the factors that increases motivation [9]. Students hope that in the VR environment they could test their own skills and get feedback instantaneously. The highest motivation to learn is achieved when the three factors described above occur simultaneously [3]. By designing a VR environment to support these three areas that promote motivation, it is possible to achieve good learning outcomes.

The teacher’s ability to design courses has a direct impact on how successful the learning process will be. As the teacher makes a decision on the use of new teaching technology, he or she also increases the number of factors to consider when designing a course. This results in a complex design challenge. Traditional content and pedagogical knowledge are still needed, but they are accompanied by a need for technological knowledge. With new emerging technologies, there is a danger that the role of technology will be overemphasized in teaching [10]. In connection with this research, this fact became apparent, e.g. in terms of how time is allocated. Although the students' IT skills were good, a relatively large proportion of the time spent on the learning task was used in the orientation of the technology.

The idea that the use of VR technology would reduce the teacher’s role as a learning facilitator is flawed [6]. The teacher must continue to lead the learning and ensure that the learning materializes. Although the VR environment frees from acquiring and learning to use physical teaching models, the successful integration of VR equipment into teaching requires a significant amount of planning and expertise. The ‘teacher as a researcher’ approach also promotes and lowers the threshold for the use of new teaching methods and equipment.

The validity of the study can be assessed from many different perspectives. The participation of the entire classes prevented bias in the sample. All students who participated in the research also returned the study forms. One factor in favor of good validity is the relatively low standard deviation of the results. However, research always has its limitations. In this case, predictive validity can be questioned. Although students found the VR environment motivating, there is not yet clear evidence that it has positive effect to learning outcomes.

5 CONCLUSIONS

Alongside teachers' pedagogical and content skills, there is a strong need for technological skills. However, technology is always just a tool. When defining the competence objectives of a course, the teacher should at the same time think about the big picture, in which the assessment of competence also plays an important role, as well as in teaching and learning tasks. At its best, VR technology offers opportunities to enrich teaching and learning situations. If the available VR environment contributes to the learning objectives of the course, its use in the light of this study is well justified.

The research described in this article will continue in the next EDR cycles. The next goal is to implement an even more precise research design and to collect data on the discrepancies in the levels of learning between the virtual and real learning environment. This is possible by implementing a learning environment with the same content virtually and with a real forest machine. The aim of further research is to find out whether it is possible to detect clear differences in the results of learning between a real and a virtual environment.

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A GAMIFIED PHYSICS CLASS FOR ENGINEERING COURSES: ELECTRICAL POTENTIAL

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ABSTRACT

Gamification can be defined as the use of game design elements, in a non-game context. This work reports the gamification of an Experimental Physics class, dealing with the concepts of Electric Potential and Electric Field, offered to Engineering students. The narrative was based on the strategy to get out of a bumped car, on the verge of fire and electrified due to a fall of a high voltage cable. We have adopted a Flipped Classroom approach to introduce theoretical contents through videos, verified by quizzes. All activities were scored and after successfully completed, gave access to the technical content of the experiment. The equipment description, electric circuits, gathering and data analysis were made available in videos. The solution to the initial problem was simulated in the laboratory and theoretically justified. The students reported great engagement and interest concerning the class. More than acquiring technical knowledge and simulating a real situation, they were proofed in situations that required decision and assertiveness to solve unexpected problems. Gamification showed to be a suitable methodology capable of engaging students, giving them more than just technical information, but also the opportunity to develop soft skills.

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1 INTRODUCTION

Gamification is defined as the use of game design elements, in a context that does not necessarily contain games [1]. Despite its increasing use in the corporate world [2-3], few applications have been done in Higher Education [4]. Gamification applied to Education is a methodology that seeks to engage students to acquire knowledge actively and, generally in an enjoyable way, making the learning process more attractive and lasting longer [5]. In Higher Education (HE), enjoyment is a secondary issue, since the emphasis is on meaningful learning and citizen consciousness since the objective is to prepare a whole professional, in academic and socio-emotional terms [6].
The game elements used in a learning activity vary according to the objectives and profile of the participants [7]. The most common are scores, rewards, and badges. Collaboration and competition, success and frustration, suspense, empowerment, gains and losses, social recognition are other viable elements. However, not all these elements need to be included in the same gamified activity. In an academic discipline, usually subdivided into topics, each one can be explored with different dynamics and elements.

Students are often introduced to Physics in the first academic years together with Mathematics and Chemistry. Usually, these students are very young and still immature, lacking in technical skills, making a multidisciplinary approach like PBL (Problem-Based Learning) very restricted. However, they are very open to new experiences and challenges.

How to teach Physics interestingly, connecting theoretical concepts to real cases, giving students hard and soft skills, while keeping them engaged while connecting their expectations to the professional world?

In this work, we report a pilot study concerning a hybrid methodology implemented in a class concerning Electric Potential and Electric Field, within the Experimental Physics discipline, offered to students of the 2nd year of Engineering courses.

The guiding questions (GQ) for this study were:

(GQ1) Is it feasible to apply gamification and flipped classroom in an experimental discipline, considering the usability of the platform (Moodle), quality, clarity and customization of content, as well the rhythm of study?
(GQ2) How is the students' acceptance of linking the access to contents, with their academic performance?
(GQ3) Is it possible to learn theoretical concepts and acquire technical skills in a gamified class?

2 METHODOLOGY

2.1 Gamification and Flipped Classroom

The storytelling was based on the strategy for safely getting out of a bumped car, on the verge of burning, and electrified due to the fall of a high voltage cable. Before the experimental activity (pre-lab) we have adopted a Flipped Classroom methodology to introduce theoretical contents (Electric Potential and Electric Field) through videos, verified by quizzes. Gamification was implemented in all activities carried out by students (access to texts and videos, quizzes, participation in forums and social networks, questionnaires, and feedback), being scored by grades, points (XP) and virtual currencies (zcoin). We have implemented the class using the Moodle platform. Virtual currencies (zcoin) and points (XP) could be implemented through Stash and Level Up plugins, respectively. Two formative quizzes (equipotentials curves: general ideas and theory) were applied and when answered with performance greater than 60%, within two attempts, students were entitled to virtual keys and zcoins, besides grades. Once obtained the 2 keys, they got access to the content of the experimental activities (objectives, experimental protocol, technical report model), finishing the pre-lab level. Students who were unable to obtain the 2 keys were submitted to new quizzes (continued recovering) until keys were earned. During pre-lab, optional contents (diversified technical information, engineering cases, and curiosities) were offered, in order to customize the class. Pre-lab level could be done anywhere (through Moodle) before the experimental activities. To help students to manage their rhythm we have suggested a schedule for activities.

After finishing experimental activities, students were required to write a structured but concise technical report (post-lab) and answered some questionnaries to evaluate the implemented hybrid methodology.

Grades obtained in quizzes (pre-lab) and in the technical report (post-lab) were used to compose the final class grade, acting as an indicator for approval in the course. The points (XP) were used only to rank students (top-5 list), acting as a competitive drive. The currencies (zcoin) were saved to be used in trading benefits in the final exam, acting as an immediate merit recognition (completion of an activity), further a facilitating agent in the execution of the final exam (expectation of success).

The equipment description, electric circuits, data collection and analysis were made available through videos, verified by quizzes. Motivating questions were asked to stimulate students' reasoning and make them more alert to details of experimental practice and interpretation of results. Thus, students have presented themselves to the experimental activity having already studied the theoretical foundations of the phenomenon, the experimental protocol and instigated by motivating questions and relevant doubts.

2.2 Experimental Activities

During the pre-lab level, students were instructed on how to determine equipotential lines produced by 2 large electrodes immersed in a water tank, connected to an AC source (12V). However, in the experiment (lab level), a third electrode, disconnected and just immersed into the tank, was added to the experimental set, aiming to produce stress in students. The new electrode simulated another car, near to the electrified one: could these passengers get out the car in safe? Since the students were prepared and were confident to deal with 2 electrodes, the objective was to remove them from the comfort zone, presenting them to an unexpected difficulty. Thus, they could observe their reactions and attitudes, while solving the new version of the problem. Once the map of equipotential curves was determined, the solution to the initial problem (leaving an electrified car) was discussed and simulated, as well theoretically justified. Having students arrived at the laboratory already instructed (pre-lab level), the class could be focused on solving and discussing the experiment and similar practical situations.

2.3 Data collection and assessment

Students' learning was assessed through two quizzes (pre-lab) and a technical but concise report (post-lab), while their participation through points (XP) and coins (zcoin). Overall considerations about the methodology were assessed through anonymous questionnaires, by open and closed questions (Likert scale). Closed questions were divided into 3 groups: (G1) structure and platform´s usability; (G2) restrictions to open contents; (G3) confidence level regarding physical concepts. Open questions collected impressions about the concise reports and general suggestions.

This pilot experiment was applied to 22 students (3rd academic semester on Industrial and Civil Engineering) during the 1st semester of 2019, on the course Experimental Physics (2 hours/week, 15 weeks, 30 hours). This article reports the class concerning Electric Potential and Electric Field, which experimental activity had aimed at determining equipotential lines due to two electrodes, immersed in a water tank. The class had been scheduled to be performed during one week: 6 days as a pre-lab level and 1 day to run the experiment (lab) and write a concise report (post-lab level).

3 RESULTS AND DISCUSSION

Data gathered from anonymous questionnaires made possible to obtain answers to our 3 guiding questions. We present here the results through the average values (axis values, on the figures and numbers within parentheses, on the text) to indicate the central trend of these data, without standard deviations, since data do not follow a normal distribution. Only the time spent by students to prepare for the experimental class is indicated in the format (mean ± standard deviation).

Students reported they have spent (2.2 ± 0.8) hours to gain access to the laboratory contents (be approved on 2 quizzes) and to prepare for the experimental class (pre-lab level). This result cannot be interpreted rigorously, since such time may have been shared with other activities and distractions. However, it suggests that the required preparation time (flipped classroom approach) is feasible, even considering that students have an average weekly workload, inside classroom and laboratories, of 30 hours.
The first group of closed questions (G1) dealt with the GQ1, that is, how feasible is gamification for an experimental course. Figure 1 summarizes these results.

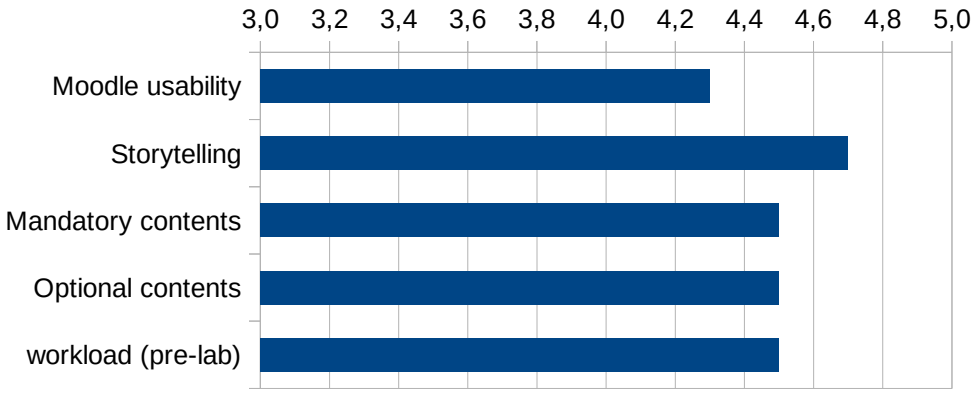

Fig1. GQ1: Feasibility of gamification in an experimental discipline, using Moodle. Likert scale: averaged values. Range: (1: unfeasible) to (5: very feasible)

Despite Moodle is not a platform fitted to gamification, its useability was not a problem (4.3). The narrative (getting out of an electrified car) was very well accepted (4.7). The students commented that it was a realistic situation and getting out in safe would require a quick and correct decision. Also, it dramatized very clearly the concept of electric potential and difference of potential. The mandatory (4.5) and optional (4.5) contents delivered were considered clear and consistent with the class theme. The optional contents allowed some customization since they were diversified and complementary to the theme. Also, they have established a meaningful correlation between physical concepts and real applications in Engineering. The rhythm of daily study and division of contents, suggested by the professor, was well evaluated (4.5). However, there was no strict control over the time of access to the contents, making it impossible to verify whether they were accessed daily (as suggested by the teacher) or in an accumulated way (last minute). These results have indicated that it is feasible to apply gamification and flipped classroom in an experimental discipline, using the Moodle platform.

The second group (G2) assessed the use of grades obtained in quizzes to provide students access to the laboratory's content. The use of quizzes to reinforce the video ´s content proved to be effective since it facilitates the perception and understanding of aspects that are not normally observed by students (formative assessment). The possibility of reviewing the video, after answering quizzes, favors attention and

perception of technical and conceptual details. Graded quizzes were well accepted (4.2) but their use to restrict access to new content had some rejection (3.8). It is important to note that all students have gained access to the contents of the laboratory. Even so, some expressed the opinion that such a restriction is not interesting, nor does it help students' development. When they were asked about their own dedication to studies, the average grade was 3.6 (figure 2).

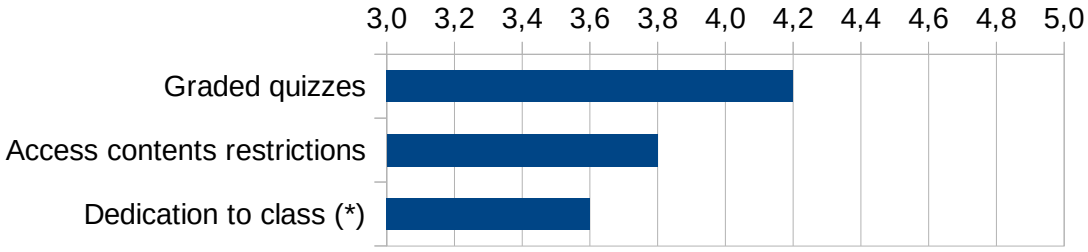

Fig2. GQ2: Restrictions to access contents. Likert scale: averaged values. Range: (1: disagree completely) to (5: agree completely). Range(*): (1: no dedication) to (5: too much dedication).

Some students did not like to be evaluated, nor to have their progress restricted by grades. However, some recognize that they did not dedicate themselves hardly to studies. This result seems to indicate that some students believe that they should progress in the discipline, regardless of their performance or dedication. Undoubtedly, any evaluation mechanism is susceptible to criticism and limitations. However, not evaluating and allowing automatic progression is also a questionable criterion, especially when we want to prepare a good professional.

The third group (G3) dealt with the student´s confidence level regarding the acquisition of technical knowledge and experimental skills. Students stated they were confident about the procedures to get out of an electrified car (4.5), about how to get closer to such accident (4.5), how to use a voltmeter (4.4) and to define the difference of potential (4.5) and equipotential lines (4.5). On a lower level (3.9), how to define the Electric Field (figure 3).

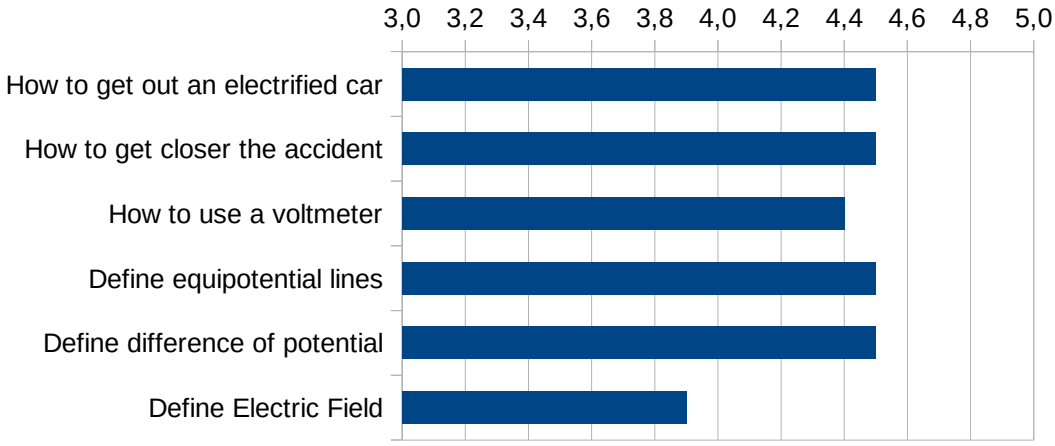

Fig3.
GQ3: Confidence level regarding technical knowledge and experimental skills. Likert scale: averaged values. Range: (1: very unsure) to (5: very confident).

These results, together with those 2 quizzes, indicate that the academic aims have been achieved. But they also indicated that the electric field concept needs to be better worked out, especially its mathematical relationship (gradient operator) with the electric potential and its physical meaning.

Open questions were formulated concerning (1) their opinion on the concise technical reports, (2) theirs impressions and self-evaluation and (3) suggestions to improve the class. The model of concise reports was praised and well accepted by all, who reported that they could be more objective and focused on the most relevant concepts and methods. Also, editing concise reports was faster, making this task more attractive and effective. To be concise and clear is a desired attitude in professional life. Students reported that the applied methodology can foster their academic performance. Part of this result can be associated with the mere fact that gamification is a novelty, regardless of any methodological value. However, the global analysis of the results indicates that acceptance of the methodology goes beyond the aspect of novelty or curiosity. The students stated the methodology can prepare them as a better professional also helping in personal development. This indicates that would be possible to promote meaningful learning and connections with the professional tasks, while developing soft skills, even in a Physics class. No suggestions were made! This seems to indicate that students are open to new methodologies and felt respected by the initiative. However, it seems that they do not yet perceive themselves as co-responsible for learning, remaining still in a passive position, although different from that typical of the traditional teaching model.

4 CONCLUSIONS

The students reported and demonstrated in the laboratory, good engagement and interest in the class. It is relevant to point out that physics classes are not usually considered pleasant, nor with easy content to be assimilated or associated with real case situations. The hybrid methodology here presented could foster the acquisition of technical knowledge (methods and physical concepts) associated with socio-emotional practices (achievement of goals, work under pressure, solving unexpected problems, group discussion, focus, etc.), from an interesting and realistic narrative (get out of an electrified car). Further, since students have arrived prepared at the laboratory it allowed a fast and full execution of the experiment and has fostered wide discussions, from concepts to applications in engineering.

These results have indicated that gamification is a feasible methodology to be applied in an experimental discipline, using the Moodle platform, without losing quality in theoretical content or practical skills, in addition to pleasing students. It represents a potential impact on engineering education, since physics classes are often classified as too theoretical and uncorrelated to real problems, inadequate to prepare engineers. However, it is important to stress that gamification or any hybrid

methodology must be changed every two or three classes, to keep students motivated and to avoid their return students to a comfort zone.

It is not possible to state whether there has been any socio-emotional development, since the classroom is not the appropriate place for effective training or assessment, and such a statement would require a long-term study. However, the mere mention that this aspect is relevant to the professional life and was considered within a Physics class, is already capable of attracting students' attention to the issue (soft skills) and to Physics (meaningful knowledge). Also, it reinforces how important are an active learning methodology and instructional design orientated to professional formation, not only in delivering information.

The trading of benefits using virtual currencies (zcoins) was performed only at the end of the course, outside the context of this article. This proposal was very well accepted and meant an extrinsic stimulus, to increase student engagement.

The hybrid methodology implemented (flipped classroom and gamification) proved to be a good way to engage students, giving them, in addition to academic knowledge, the opportunity to think about soft skills. It must be stressed that this pilot experience was performed in the 3rd academic semester when students are still running the basic disciplines, with few contacts with Engineering contents. Furthermore, it must be observed that newcomer students usually are open to new experiences and are very enthusiastic about active methodologies, despite the previous experience with traditional and passive education. It suggests that basic disciplines must be designed to be considered as key elements in Engineering Education, not only to deliver technical information but to established robust grounds for a good professional!

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CURRICULUM THROUGH THE MARKET LENS – MINING VACANCY DATA FOR FUTURE-PROOF ENGINEERING EDUCATION

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Conference Key Areas: *Future engineering skills, HE & Business, Career support*
Keywords: *curriculum, labor market, career*

ABSTRACT

Curricular design presents a constant challenge in engineering education amid the ongoing technological revolution. In fast-moving disciplines like computer or software engineering, a mismatch between the curriculum and market demands can develop rapidly over the course of years. Failure of an engineering program to match market requirements can lead to decreased students' satisfaction and, consequently, to dropping acquisition and retention rates.

Traditionally, the level of the curriculum coverage is benchmarked with alumni and company surveys. Both of these approaches incur financial costs, have poor response rates and suffer from intrinsic biases. Here, we present an alternative market analysis method and show how it can be used to aid curricular design. The method uses information scraped from job advertisement aggregators and employs data mining to discover current market demands.

This process is automated in a software tool. The tool employs search criteria and filters to download vacancies targeted at starting engineering professionals. The bodies of the advertisements are subsequently processed using text transformation and mining techniques to collect importance-weighted terms falling under one of the three categories: tools, techniques and concepts. Finally, the processed data is augmented with geographical information to enable geospatial analysis and visualization.

We demonstrate the usage of this method on a bachelor curriculum of an embedded software engineering program in the Netherlands. We show how the results of the job market analysis help discover courses with low relevance, at the same time highlighting curricular underrepresentation of some highly sought-after skills.

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1 INTRODUCTION

The European labor market has been undergoing a steady growth with the number of unfilled posts increasing by almost 50% in the past five years as measured with the *job vacancy rate* indicator [1]. This process is amplified in the ICT industry, which experiences very rapid employment development [2]. In the Netherlands the situation on the ICT labor market is the worst among all the professions; employers in this sector report that 70% of the vacancies are difficult to fill in. Notably, positions targeted at graduates of tertiary education programs account for 78% of the openings. Often, knowledge of specific programming languages or techniques is required, which further aggravates difficulties with finding a fitting candidate [3]. Given this situation, ensuring that ICT graduates have mastered the skills and knowledge that match the market demands not only increases their chances to find a job but also helps to alleviate the problem of understaffing. Well-prepared starting employees need less internal training shortening the time to reach full work efficiency.

Curricular design that closes the gap between ICT students' competences and industrial needs poses a persistent challenge. Some educational institutions approach it by following established curricular guidelines that are updated every few years by panels of international industrial and academic experts [4]. Others employ alumni surveys to measure the discrepancy between teaching practices and perceived importance of knowledge and skills in professional settings [5]. Both of those methods incur financial costs and suffer from intrinsic biases; composition of panels or survey audience strongly affects the outcomes. Moreover, both approaches have intentionally broad scope. Curricular guidelines have word-wide reach and are presented in a way that makes them adaptable to local circumstances, yet they lack details. Similarly, alumni studies recruit respondents across multiple industries and specializations to collect responses that guarantee sufficient statistical power [6]. Consequently, they identify mostly high level features like *design* or *quality* [7] that need to be subsequently translated into concrete curricular items. University programs faced with redesigning or adjusting their curricula struggle with adapting those guidelines and survey outcomes, relying on the expertise and personal preferences of their teaching staff.

Recently, another approach to discovery of qualifications expected from perspective ICT employees has been demonstrated. It applies topic modelling to a dataset of publicly available vacancy advertisements, to compose a throughout overview of job roles together with corresponding knowledge and skills [8]. We propose to extend this idea by applying data extraction techniques instead of performing exploratory analysis on a vacancy dataset. This way, more detailed market information can be obtained, leading to cataloging industry requirements relevant to a specific study program.

In this article, we describe this method, showing the collection and preparation steps necessary to create a vacancy dataset that is limited geographically, bound to a study profile and restricted in scope to postings relevant to junior employees. We

follow by describing data extraction based on keyword matching and analysis that results in a detailed snapshot of industry demands specific to a particular educational program's offering that can be readily applied as a base for curricular (re-)design. We show how this method is used to extract market requirements relevant to a program of *embedded software engineering* in the Netherlands and how this information was used to start an ongoing curriculum redesign.

2 METHODOLOGY

2.1 Data collection and pre-processing

Jobs are posted daily to numerous websites. To get the best possible representation of the market we used *Indeed*, a website that's a vacancy posting aggregator as a data source. Queries submitted to *Indeed* can contain phrases and use Boolean operators, which allows for composing complex requests. Moreover, the queries are always limited geographically by providing the target location and the search radius with a maximum of 100 km. The postings found on *Indeed* contain, next to the body of an advertisement, a unique identifier, a job's title, a company's name, a date of placement and a geographical location either as a city name or a postal code. This allows for post-collection filtering of data and focusing on a specific region or filtering out advertisements for senior positions.

We constructed the dataset by querying the vacancy website for 8 distinct geographical locations, making sure that the search areas overlapped and covered the whole country. For each location we used 7 search queries, relevant to the *embedded software engineering* program, such as: *embedded AND software*, *embedded AND engineering, embedded AND programming* and their local-language equivalents. One of the queries was a phrase containing the explicit study program name. *Indeed* uses a full-text search, guaranteeing that most of the postings related to the study program at hand were found. While gathering the data, only advertisements with the unique identifiers not yet present in the dataset were downloaded. Next, the text duplicates were removed using cosine similarity score calculated on *term frequency – inverse document frequency* embeddings of the 250 first words of each posting.
The remaining vacancies were filtered in a three-stage process that consisted of:

1) Removing advertisements belonging to known companies that specialize in internship recruitment only.
2) Removing entries based on keywords present in titles; in this step vacancies that addressed *senior, experienced, principal, leader, manager*, *internship,* and other non-relevant functions were dropped. In total there were 46 different direct match filters used in this step.
3) Removing advertisements that contained a requirement of more than four years' experience in the text based on regular expression matches.

Once the vacancies were collected, the following text transformations were applied to their bodies before performing any further steps:

1) Unicode codepoints replacement, for instance both *\u00b5controller* and *\u03bccontroller* were replaced with *microcontroller* (\u00b5 and *\u03bc* are the Unicode codepoints for the Greek character μ)
2) Known equivalent notation replacement, for instance both ucontroller and *micro-controller* was replaced with *microcontroller*.
3) Global synonym replacement – some words occur very infrequently in the dataset but can be replaced with a more general term, for instance both *Pic* and *Atmega* were replaced with *microcontroller* (*Pic* and *Atmega* are microcontroller families).

Subsequently, the geographical locations of the advertisements were encoded into longitude and latitude using geographical database lookup.

2.2 Feature extraction

2.2.1 Keywords counting

Advertisements targeted at ITC professionals are usually very specific and contain well-defined required skills' sets. For that reason, keyword counting with importance weighting was used for extracting the features from the vacancies. The bank of pre-defined keywords consisted of terms related to skills and knowledge items, grouped under three categories:

1) *Languages*, this category held programming languages, e.g.*: C++, Java, Python.*
2) *Techniques*, this category grouped keywords related to skills that usually can be taught during a single, semester-long course, e.g. *databases, Linux, Bluetooth*.
3) *Concepts*, this category contained terms that describe high-level concepts for which familiarity with multiple techniques is often necessary, e.g.: *testing, machine learning, agile*.

At this stage, advertisements that contained no matching keywords were removed from further analysis. For the remaining vacancies, both the occurrence of a keyword and the order of its appearance in the advertisement text was recorded. Based on this data a simple weighting scheme was applied for counting the keywords across the whole dataset. First, the following statistics were calculated for the number of unique keywords found per advertisement: the median (*M*) and the interquartile range (*IQR*). Subsequently, two boundaries were defined:

$$\begin{cases} FC = M + \frac{IQR}{2} \\ NC = M + 2 \cdot IQR \end{cases} \quad (1)$$

The FC boundary is the 75 percentile of the keyword counts per advertisement distribution, whereas NC sets up a limit of the normal observations – advertisements containing more or equal than NC keywords are outliers in the dataset.

$$c(i) = \begin{cases} 1, & i \leq FC \\ \frac{NC-i}{NC-FC}, & FC < i \leq NC \\ 0, & i > NC \end{cases} \quad (2)$$

The weighting scheme was used as follows (Eq. 2): if a keyword appeared among the first FC keywords in a vacancy description it was counted as one. A keyword appearing after the first FC keywords but before the first NC keywords was counted using a linear scale going from one for FC to zero for NC. Keywords that appeared after the first NC keywords in a text were not counted. The application of weighting was meant to counteract the practice used by some agencies and employers of putting multiple, often non-relevant terms in an advertisement with the hope of getting more search hits. After processing each vacancy, the counts obtained this way were summed up across the whole dataset, producing an overall count for each keyword, c_k.

2.2.2 Data analysis

The keyword counts were used to derive two quantities: the keyword frequency (f_k) and the keyword proportion (p_k). The keyword frequency is the occurrence count of a keyword divided by the total number of job advertisements (Eq. 3). The keyword proportion is the fraction of the occurrence count of a keyword and the sum of all the keywords' counts (Eq. 4).

$$f_k = \frac{c_k}{N} \quad (3)$$

$$p_k = \frac{c_k}{\sum_i c_i} \quad (4)$$

While, keyword frequencies make it straightforward to gauge which skills are in high demand, keyword proportions can be used when assessing the curriculum coverage of a study program.

2.2.3 Curricular coverage

A keyword proportion (p_k) represents the share of market demand of a knowledge item associated with a keyword. As such it can be compared with the corresponding study load share expressed as the fraction of the ECTS points allocated to learning related content. When there is a match between the market demand share and the study load share, once can conclude that the curricular coverage of the related skill or knowledge item is adequate. Otherwise there is either under- or overrepresentation of a topic in the curriculum. To calculate the approximate study load of each knowledge item in a curriculum, the learning objectives of all the courses in the study program were analyzed and linked to knowledge and skill items. Next, a fraction of the ECTS points of a course was assigned to an associated keyword. For instance, for a semester-long, 6 ECTS course in operating systems

that teaches OS concepts using Linux but also offers practice in writing drivers and tools for this system, 2.4 ECTS might be allocated to learning Linux, while the remainder would go to advance practice in the C programming language.

To assess the curricular coverage, the ratio R_k between the study load share and the market demand share was calculated. If the ratio for a knowledge item was between 0.5 and 2.0, the curricular coverage was considered adequate within the limits of this study[2]. Consequently, for R_k lower than 0.5 the curricular coverage was inadequate, while for R_k greater than 2.0 an item was judged to be overrepresented in the curriculum.

3 RESULTS

3.1 Data collection and market requirements

In total 2530 advertisements with unique identifiers were found and downloaded. After subsequent filtering steps this count was reduced to 866 unique vacancies targeted at young professionals with *embedded software engineering* background. The exact counts of items dropped at each filtering step can be found in Table 1. The five most common terms occurring in vacancies' titles that resulted in their removal were: *internship* (393 matches), *graduation assignment* (213) *senior* (132) *architect* (68) and *lead* (53). In the phrase filtering phase most vacancies (21) were excluded because they contained the requirement of "*5 years of experience*".

Table 1. Vacancy counts after subsequent filtering steps.

Procedure	Count removed	Count left
Vacancy scraping	---	2530
Title filtering	1148	1382
Internship companies	369	1013
Phrase filtering	33	980
Duplicate removal	66	914
No keywords found[3]	48	866

The locations of the vacancies were not evenly geographically distributed (see Figure 1), the north-east part of the country received particularly few hits, despite the presence of a vocational university that offers an *embedded software engineering* program in this area.
There were 4550 keywords found among the whole dataset with a mean of 5.25 keywords per advertisement (stdev=3.1). The median keywords count per advertisement was 5 with the IQR of 4. Consequently, when counting the keywords

[2] Those limits, corresponding to "the market requirements are two times greater" and "the curricular coverage is two times too big" were chosen arbitrarily.
[3] This step was performed only after feature extraction.

for further analysis, those that appeared after the 13th place (M + 2·IQR) in the body of an advertisement were skipped.

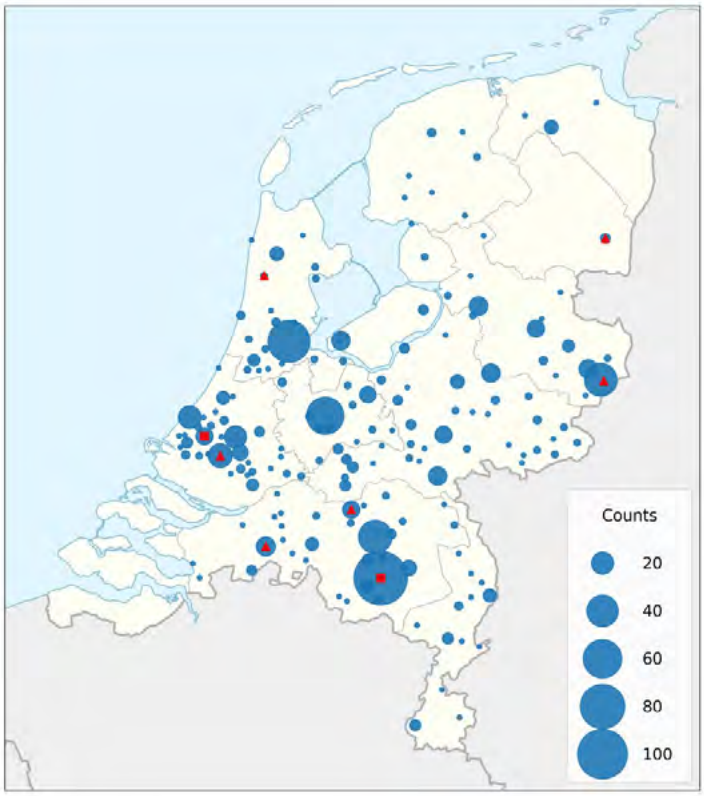

Figure 1. Geographic distribution of the vacancies. Schools that offer Embedded Software Engineering as a primary study program are marked with ■ (research universities) and with ▲ (vocational universities).

In Table 2 the first 15 most frequently occurring keywords in each of the three categories are listed. The most sought after programming languages are C and C++ (belonging to a group of systems programming languages), which contrasts with the results of other surveys where languages like Java and Python are usually in the lead [9]. This is the consequence of the strong presence of embedded and system development positions among the advertisements.

Table 2. The 15 most frequent keywords in Languages, Concepts and Techniques categories. (f_k – keyword frequency; p_k – keyword proportion).

Languages			Concepts			Techniques		
Keyword	f_k [%]	p_k [%]	Keyword	f_k [%]	p_k [%]	Keyword	f_k [%]	p_k [%]
c++	41.9	8.2	agile	25.5	5.0	linux	22.0	4.3
c	37.4	7.3	testing	21.0	4.1	databases	17.7	3.4
c#	20.9	4.1	scrum	20.8	4.1	real-time	16.0	3.1
java	16.8	3.3	electronics	17.2	3.3	plc	13.5	2.6
python	16.6	3.2	mechatronics	11.9	2.3	networking	13.4	2.6
js	10.2	2.0	oop	11.7	2.3	sql	11.4	2.2

Languages			Concepts			Techniques		
Keyword	f_k [%]	p_k [%]	Keyword	f_k [%]	p_k [%]	Keyword	f_k [%]	p_k [%]
html	9.8	1.9	cloud comp.	10.8	2.1	uml	9.4	1.8
matlab	6.0	1.2	vcs	10.0	1.9	ucontrollers	7.2	1.4
php	3.5	0.7	ci	9.2	1.8	iot	6.5	1.3
simulink	2.5	0.5	robotics	7.7	1.5	fpga	3.8	0.7
assembler	2.2	0.4	algorithms	6.8	1.3	scada	3.8	0.7
vhdl	2.1	0.4	math	6.5	1.3	arm	3.8	0.7
labview	2.0	0.4	machine learning	5.4	1.1	ethernet	2.5	0.5
delphi	1.5	0.3	control systems	3.0	0.6	embedded protocols	2.4	0.5
visual basic	1.3	0.2	machine vision	3.0	0.6	bluetooth	2.0	0.4

In the *Concepts* category, besides terms associated with the software engineering practice like *agile*, *scrum, testing* and *version control systems (vcs)* there are terms that can be linked to hardware development (*electronics*, *mechatronics*, *robotics*, *control systems*) but also skills that require mathematical background (*algorithms*, *machine learning* and simply *math*ematics). The appearance of the latter group may be related to the fact that many traditional *software engineering* programs in the Netherlands dropped mathematics altogether from their curricula, however, it is still taught during a standard *embedded software engineering* course. Employers know about it and seek *ESE* graduates for positions that require mathematical competences.

The keywords appearing under *Techniques* are mostly related to embedded development, besides *databases* and *sql* (*Structured Query Language*, a language used only with databases). The reason for the strong presence of those two is perhaps the same as for *cloud computing* in *Concepts*; the emergence of Internet-of-Things and connected embedded devices that routinely communicate with cloud services and store their data in online databases.

3.2 Curriculum coverage

In Table 3 the results of the curricular coverage analysis for the assessed *embedded computer engineering* program are shown. Only items that had at least 1 % market demand share (p_k) are listed, unless they were represented in the curriculum. The items are sorted in the ascending R_k order (from the most underrepresented to the most overrepresented).

Table 3. Comparison of keyword proportions (p_k) and ECTS shares (p_{ECTS}) in the analyzed curriculum. The ration R_k between p_{ECTS} and p_k is considered within norm if it falls within the 0.5 – 2.0 interval.

	Keyword	p_k [%]	ECTS [-]	p_{ECTS} [%]	R_k [-]
underrepresented	c#	4.1	0	0	0
	real-time	3.1	0	0	0
	plc	2.6	0	0	0
	mechatronics	2.3	0	0	0
	cloud	2.1	0	0	0
	ci	1.8	0	0	0
	robotics	1.5	0	0	0
	machine learning	1.1	0	0	0
	python	3.3	0.8	0.7	0.2
	agile	5.0	1.8	1.6	0.3
	oop	2.3	0.9	0.8	0.3
	c++	8.2	3.6	3.2	0.4
	testing	4.1	1.8	1.6	0.4
	linux	4.3	2.1	1.9	0.4
adequate	databases	3.4	2.4	2.1	0.6
	vcs	1.9	1.8	1.6	0.8
	matlab	1.2	1.2	1.1	0.9
	networking	2.6	3.0	2.7	1.0
	uml	1.8	2.4	2.1	1.2
	assembler	0.4	0.6	0.5	1.3
	algorithms	1.3	2.4	2.1	1.6
	iot	1.3	2.5	2.2	1.8
	java	3.2	7.2	6.4	2.0
overrepresented	c	7.3	21.8	19.5	2.7
	microcontrollers	1.4	5.5	4.9	3.5
	fpga	0.7	3.0	2.7	3.6
	build systems	0.4	1.8	1.6	4.3
	control systems	0.6	3.0	2.7	4.6
	electronics	3.3	24.1	21.5	6.4
	math	1.3	15.3	13.7	10.7
	dsp	0.2	3.0	2.7	17.0

Moreover, *scrum* and *sql*, were skipped in this listing, as they always appear with respectively *agile* and *databases* in the advertisements and are also taught together.

Remarkably, only 9 out of the 23 skills / knowledge items seem to be represented in the curriculum in a proportion that's close to the labor market needs. When looking at the overrepresented items, *digital signal processing* (dsp), *control systems* and *field programmable gate-arrays* (fpga) all have less than 1 % market demand share, while being taught in a dedicated 3 ECTS course each. *Mathematics* and *electronics* also seem to be taught too much, however, at least in the case of mathematical skills an argument can be made that they form the basis for other courses and are rarely mentioned directly in the advertisements because most employers assume knowledge of college level mathematics in university graduates.
Even more striking is the list with items that are not a part of the curriculum but there is a substantial market demand for them. *Real-time system*, *programmable logic controllers (plc)*, *mechatronics* and *cloud computing* all seem to deserve a place in the study program – the market demand share for them corresponds to around 12 ECTS study load.
There is also a mismatch between what programming languages the employers seem to require and what the curriculum offers. For systems programming, the demand for C++ is somewhat greater than for C, yet in the curriculum those proportion is completely reversed, only 3.6 ECTS are allocated to learning C++, while 22 ECTS go to teaching and practicing C. The market requirements shouldn't be surprising, considering the ubiquitous presence of high-level microcontrollers, that are usually programmed with C++, in embedded system nowadays. A similar observation can be made for Java and C# programming languages. The labor market clearly prefers C#, whereas the analyzed study program teaches the former.

Overall, there seem to be a remarkable discrepancy between the composition of the curriculum and the market needs.

3.3 Curricular re-design

In light of the findings presented in this study, the first steps were made to align the analyzed study program curriculum with the market demands. Since the scope of the redesign is big and concerns all the study years, in the beginning the courses of the first program year have been changed. Electronics courses worth 6 ECTS were removed from the curriculum. Those study points went into strengthening the underrepresented software engineering skills*: cloud computing, testing* and *object-oriented programming* design (*oop*). Moreover, the balance between the programming languages taught was adjusted by promoting C++ to the main teaching language and, consequently, changing the language from C to C++ in some courses. Additionally, Java courses were replaced by a mix of C# and Python modules.
The curriculum will undergo further transformations, after the modifications in first-year courses will have finished. The focus will shift to the advanced curricular items, like replacing *digital signal processing* (dsp), *control systems* and *field programmable*

gate-arrays (fpga) with more demanded *real-time system*, *programmable logic controllers (plc), continuous integration (ci)* and *machine learning*.

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FEATURES AND TRENDS OF EDUCATIONAL CHANGES' APPROACHES IN WORLD-CLASS ENGINEERING UNIVERSITIES: BASED ON RESEARCH OF THREE UNIVERSITIES

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ABSTRACT

The spread of COVID-19 and other 21st century's grand challenges of the have propel led the global process of engineering education transformation. Therefore, how to choose an appropriate path of education change in the coming years, and quicken the pace for the provision of high-quality and large-scale education engineering is of great significance for lots of universities and colleges, since they must grasp the historical window period for the adjustment of global engineering education leadership landscape. From the perspective of institutional entrepreneurship, this paper has viewed the engineering education changes in universities as a process in which universities acquire resources to create new institutions or change existing ones in different field conditions and under different circumstances. This paper is based on the theoretical framework of institutional entrepreneurship, introduces legitimacy as a theoretical tool, and selects three world-class engineering universities, that is MIT (USA), Tsinghua University (China), and TU Delft (Netherlands) under different educational systems for case studies and inductive logic analysis of their significant education changes in the past ten years. This paper has drawn the features and trends of these universities in developing education change programs or initiatives vis integrated comparison to provide some useful insights to new participants endeavoring to change in engineering education. It may also make some knowledge contribution to the engineering education community.

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1 INTRODUCTION

1.1 Background

Engineering education has always reflected the social and economic needs and changes. However, from a historical point of view, higher engineering education has gradually lost students' preference for engineering majors in the enrollment market, and the graduate employment market is also facing a situation where enterprises' recognition of cultivating talents is reduced. A significant reason is that engineering education in universities has maintained the traditional education models for most students. Therefore, the engineering education community has always regarded educational reform as one of the crucial issues of its research list. There is such a long road for engineering education change yet. Some researches suggest that this is due to the powerful anti-change forces that are associated.[1] Based on the network location theory, several universities at the center of engineering education systems come up with facts that they have presented the top engineering education quality nationwide, so they do not have to change. In contrast, universities on the edge of the network are always limited by material and technical resources but may have the will to change. This situation may lead to collective silence among engineering universities to preserve the status quo.

1.2 Purpose

Regarding the question of how universities should carry out engineering education changes, two very different views emerged in the existing research. It may be due to the widespread resistance to change in colleges and universities. Some studies believe that although each university's engineering education change is not suitable for a one-size-fits-all solution, a university adopts an incremental change plan based on its partial proved successful experiences and suits its reality is still the mainstream path of change in engineering education. [1] However, other scholars have found successful transformative initiatives usually avoid the incremental approach, but adopt radical and systematic approach instead, based on the survey results of engineering education programs in multiple countries. [2]

The American Journal of Engineering Education published a special issue of "The Complexities of Transforming Engineering Higher Education" in 2014. It pointed out that since the engineering education community has made a lot of contributions to the reform process, models of specific courses and curriculum, engineering educators and researchers should strengthen the knowledge base focused on the systematic educational change programs and initiatives of universities by more participation. [3]This study is based on the multi-situational institutional change process framework of institutional entrepreneurship theory. It summarizes the features and trends of the world-class engineering universities in carrying out significant educational change programs or initiatives by multi-case and inductive logic analysis[4]. It attempts to contribute to presents some worthwhile observations of systematic education change in engineering education and provide some useful insights into new global participants with on-

going efforts in engineering education. In this study, a university's engineering education (significant) change refers to the programs or initiatives carried out using rigorous methods and convincing evidence based on extensive investigations.[5]

2 METHODOLOGY

2.1 Research approach

Seely B.(1999) shared that "perhaps the most constant feature of American engineering education has been the demand for change" after reviewing American engineering education history. It applies to engineering education not only in the US but also in Asia, Europe, and the world. To enhance sufficient quality of the data in this study, we adopted the following criteria for selecting the case study objects: firstly, It provides the world-class education quality recognized by the engineering education community; secondly, it has developed at least one significant education change in the past ten years, and the results of the change have significantly improved or consolidated its reputation and status in engineering education; thirdly, it represents the geographical location, national institution system and background of a specific type of engineering universities; finally, it has sufficient records for the historical documents and of major events of its educational changes[4].

Based on these standards, With the literature work and knowledge of the global engineering education community, we choose the case studies from the top ten universities of both "current leader" and "emerging leaders" identified in MIT's influential report(2018) "The global state of the art in engineering education," which are the Massachusetts Institute of Technology in the United States, Tsinghua University in China, and the Delft University of Technology in the Netherlands eventually.

2.2 Research design

2.2.1 Theoretical orientation of institutional entrepreneurship

Institutional entrepreneurship has now become synonymous with institutional change. The concept of institutional entrepreneurship was proposed to find a solution to the "Paradox of Embedded Agency." When DiMaggio(1988) first explained institutional entrepreneurship's phenomenon, he believed that "new institutions arise when organized actors with sufficient resources see in them an opportunity to realize interests that they value highly." [6] His statement mentioned a sequence: the actors of the organization firstly have sufficient resources, then find opportunities for institutional entrepreneurship, and it refers more to the centric organizations' institutional entrepreneurship in a mature field. To avoid the discussion of complex elements in the institutional entrepreneurship process, Dorado(2005) comprehensively discussed three general factors commonly define institutional entrepreneurship, field condition, agency, and resource mobilization, and proposed ten different combinations, which clarified the conceptual relationship between the three factors, and formed a framework for research on institutional change under various circumstances. [7]

This article aims at the world-class engineering universities that have carried out significant engineering education changes, which are generally in the field of a complete and open engineering education system. For focusing on the research purpose

and consciously breaking out of the “complex dilemma” of engineering education changes’ research in universities, we targeted the field of “opportunity transparency” in Dorado’s work as the initial theoretical framework (Table 1).

Table 1. The initial theoretical framework

Field Condition：Opportunity	Agency	Resource mobilization	Profile
transparent	strategic	leverage	entrepreneurship
		accumulation	partaking
	sensemaking	accumulation	partaking
	routine	accumulation	partaking

2.2.2 Legitimacy mechanisms as the theoretical tool

The evolution of organizations not only stems from the pressure of technology and material resources, but also from the constraints of social and cultural norms, symbols, beliefs, and customs[8] such as "legitimacy," which is emerged as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" in the 1990s.[9] Legitimacy is one of the core ideas to explain the convergence of organizational system structure. It comes from people's perception of whether a thing or action meets norms and expectations, and generally has been divided into three types, regulative legitimacy, and normative legitimacy, and cognitive legitimacy.[10]

From a strategic perspective, legitimacy is an invisible and essential resource that can help an organization obtain other resources. Organization managers or institutional entrepreneurs can actively obtain legitimacy in purposeful approaches, which is reflected in multiple phases of institutional entrepreneurship six phases-process-model in the mature field that is comprehensively sorted out by Greenwood et al. (2002). As center organizations in mature fields, benchmarking universities enjoy vested interests in an engineering education system with sufficient resources in terms of material and technology. Therefore, introducing different legitimacies’ acquisition into the research on transformation models of engineering education may have the opportunity to unify the divergence of views mentioned earlier in 1.2. Thus we expand the initial framework as follows (Table 2).

Table 2. The theoretical framework embodies legitimacy mechanisms

Field Condition：Opportunity	Agency	Resource mobilization			Profile
		regulative legitimacy	normative legitimacy	cognitive legitimacy	
transparent	strategic	leverage			entrepreneurship
		accumulation			partaking
	sensemaking	accumulation			partaking
	routine	accumulation			partaking

2.2.3 Data sources

We collected the data from three sources: (i) information related to engineering education changes from the three universities' website during 2013-2020; (ii) 17 articles of journals or conference proceedings from professional association publications (ASEE, CSEE, and SEFI), which are about the effort of the three universities to transform engineering education; (iii) the related introduction report such as "The global state of the art in engineering education" and policy documents.

2.2.4 Data analysis

The research adopted the case study research method. It had three professional associations' publications as the starting point of analysis and compiled the three universities' major events in the process of engineering education changes.

Secondly, employing "snowballing," we track the detailed descriptions of various initiatives during the three universities' education change processes to form the strategic items adopted by each university in each major event. Then, according to the institution entrepreneurship strategy set, the strategies corresponding to each event are generally coded.

Thirdly, the resource types of legitimacy are identified from the established strategies' general codes with each strategy's influence on the change process, based on the iteration of literature analysis, three universities' official information, and reports.

Fourthly, under the expanded theoretical framework, we identified the features and trends of world-class engineering universities' education changes under different backgrounds.

2.2.5 Limitations

It should be acknowledged that the case-study method will have shortcomings that cannot be generalized due to the small sample size in qualitative research. In order to discover the generalities in the three universities' changes as much as possible, the study improved the existing theoretical framework of institutional entrepreneurship under multi-circumstances and selected the two possible change paths of three world-class engineering universities with different national backgrounds.

It is almost impossible to make the three universities perform engineering education changes entirely during the same period, and it is hard for horizontal contrast. Since the transformative process always includes two phases, the gestation phase, and the implementation phase, the study can assure the main critical period (2016-2020) that spanning the boundary between two phases can be covered.

Table 3. An integrated comparison between the engineering education changes in three universities

	MIT		Tsinghua University		TU Delft	
National context	· cope with the 21st century's grand challenges · maintain global leadership · transforming undergraduate education in engineering		· aim to become an engineering education power · urgent need to improve the quality and deepen comprehensive reform in higher education		· usefulness-oriented problem-solving · nationwide cooperation culture	
University's context	· lead future development · respond to major challenges · develop MIT community' the ability and passion		· persist in serving the country · take national higher education reform pilot tasks · strive for self-improvement and excellence		· solve social problems · fewer bureaucracies · inclusive and egalitarian	
Significant education programs	New Engineering Education Transformation （NEET, 2016-2020）		Tsinghua University Comprehensive Reform Plan （TUCRP, 2012-2020）		TU Delft Strategic Framework （TUDSF, 2014-2020）	
Change phases	Gestation	Implementation	Gestation	Implementation	Gestation	Implementation
Major events (Only list partly)	· formulated NEET approach · gathered documented evidence, and survey· worked on pilot threads, NEET curricular &freshman programs · launched the process of building the NEET community...	· launched four pilot threads, plan for upgrading them to 3/4th-year program · evaluated the program and departments' thread proposal requests · NEET seminars, marketing and recruiting students · cross-school initiatives, thread community plan... · **explore threads to 3/4th-year program&planned degree programs**	· undertook the task with Ministry of Education'approval · gathered stakeholders' suggestions of the preliminary plan... · Tsinghua's 24th educational work discussion · **the state approved the Reform Plan**	· reform of personnel system · new education system& programs mechanism...· reconstructed programs' plan based on a global investigation· four departments' pilots · Tsinghua's 25th educational work discussion · **TUCRP Summary Working Group**'s working for follow-up advancement	· a department's Education Director published an influential report caused broad discussion · announced the start of an institution-wide strategic framework process · launched several initiatives · the establishment of Teaching Academy...	· articulated TU Delft's educational vision · released **TU Delft Strategic Framework 2018-2024**
Action strategy(Agency)	the framework, bridging diverse stakeholders, creating standards, building coalition...	creating standards; educating, routinizing, embedding; constructing identities; building coalition; bridging diverse stakeholders...	taking what the system gives; bridging diverse stakeholders; direct authority...	bridging diverse stakeholders; justification; creating standards; attaching routines, mimicry; building coalition...	stories; advocacy; taking what the system gives; bridging diverse stakeholders...	educating, routinizing, embedding; framework...
Resource mobilization*	1	1-2	1-2	2-3	2	2-3
change approach	incremental change		systemic change		incremental change	

Note: * means the average value of three types of legitimacy resources(regulative/ normative/ cognitive legitimacy) acquired for each major event at a specific stage.

3 RESULTS

3.1 Features of significant engineering education changes in three universities

Under the influence of the educational values and organizational culture, the three universities have adopted a gradual or radical way to blaze its own engineering education change "road" across the campus with its characteristics. (Table 3)

3.1.1 MIT

MIT upholds the values of leading the future development, bearing on the world's grand challenges, and developing in each member of the MIT community the ability and passion. The university academic leaders believe any change requires a change in culture that builds on the university's values.[10] MIT's institutional entrepreneurs preconceived a future-oriented and feasible action framework, adopting a strategic agency to guide the behaviors of the MIT community consciously. For example, all departments of the School of Engineering are required to engage in the development of pilot threads gradually, then it comes to the fulfillment of threads, curriculum, and restructured degree programs. MIT also innovated NEET's multi-disciplinary groups under teachers' and students' co-governance at the very beginning and has made specific plans for building the NEET communities to guide the community members' behavior. From the gestation phase to the implementation phase, the accumulation of legitimacy types shows an increasing trend, ensuring MIT's trigger for large-scale engineering education changes after 2020.

3.1.2 Tsinghua University

Tsinghua University has undertaken one of the reform pilot tasks under the national medium and long-term educational reform and development requirements and the responsibility of benchmarking universities, striving to explore resolutions firstly in the national deepening education reform field and accumulate extensional experience. After the state-approved Tsinghua's TUCRP initiative in 2014, the university has conducted the change from the “up-bottom," following TUCRP. In this process, the following senior use of political skills. For example, the university first "wielded the sword” at its own teachers’ personnel system, which is widely considered to cause high resistance to change, and abandon the local "incremental reform" that can temporarily avoid contradictions, but directly transformed the management system for teachers overall. By the leveraging approach of agency, its senior managers have acquired a large number of legitimacy resources, especially with the dominant role of regulative legitimacy.

3.1.3 TU Delft

TU Delft has a profound consensus-building culture and the unique "Delft spirit."[11] The report "Engineering Education in a Rapidly Changing World" written by a department's Director of Education sparked horizon-scanning debates both within and spanning the boundary of TU Delft. Then TU Delft is embodied in that after an influential report, "Engineering Education in a Rapidly Changing World" written by a department's Director of Education sparked horizon-scanning debates both within and spanning the boundary of TU Delft. After that, the university has established 4TU, launched seminars, built up its "Free Spirit Think Tank" and the Teaching Academy, formed its first

university-wide educational vision statement, and then released the Strategic Framework. TU Delft did not follow the "Means-End Chain," but went the way that all the active participants firstly gave meanings to the current situation based on their understandings, formed the identical concepts, and then constructed, refined, formed a framework, and launched a clear action strategy. The action strategy approach makes the university's agency at each phase focused on accumulating a variety of legitimacy types and ultimately promoting a large-scale change.

3.2 Trends of educational changes' approaches in world-class engineering universities

3.2.1 Both incremental and systemic changes will become effective choices for the path of education change

The three universities are gradually and cautiously advancing the process of change, moving in the direction of widespread sustainable change. Indeed, some inquiry results show that good practices of a specific curriculum or course can provide a model for the same department, but they are not enough to drive the university's overall engineering education change. However, through interdisciplinary projects work and a project-based curriculum organization mode, incremental changes have made it possible to provide the teaching approaches and methods for the faculty with a broader professional field. For example, MIT did not require all departments of the School of Engineering to participate in the initial pilot thread task in the process of change. The cross-professional and interdisciplinary characteristics of the thread task enable all relevant departments to engage in a relatively short time. At the same time, there is evidence that systemic change is also a valid path. Tsinghua University completed the restructuring of the overall education programs early. It also adopted the four departments of the School of Mechanical Engineering as enrollment and education pilots of the new programs and then completed the new programs across the campus.

3.2.1 Purposeful acquisition of legitimacy resources has the potential to become a basis for examining whether the education change will maintain the sustainability and effectiveness

From the perspective of engineering education changes' launching approaches, both MIT and TU Delft are incremental, while Tsinghua University is radical and systemic. No matter which kind of change, the legitimacy resources acquired in the implementation phase are more than those in the gestation phase. Every major event will be accompanied by the acquisition of at least one type of legitimacy resource during the engineering education change process. Legitimacy can bring consistency and credibility to universities' engineering education changes, and the more legitimacy types acquire, the more they will promote the community members' consistency of in their actions, and the trust and cultural identity' formation in the cognition. [12]

4 SUMMARY

This study has performed a multi-case and inductive logic analysis of significant educational changes developed by world-class engineering universities under the theoretical framework of institutional entrepreneurship. It also introduced legitimacy as a

theoretical tool to discuss agency and resource mobilization in each university's educational change process. This research approach has realized the horizontal comparison of engineering education changes carried out by three different universities, which are in the engineering education systems of the US., China, and a European country. To some extent, It may solve the problems of complexity and ambiguity when studying the common analysis of engineering education changes in transnational universities. It also provides some valuable observations for the universities with great interests to develop a radical systematic educational change in engineering education and some insights for more new participants who endeavor to upgrade the leadership in the engineering education sector.

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CONCEPT PAPERS

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TOWARDS GRADING AUTOMATION OF OPEN QUESTIONS USING MACHINE LEARNING

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ABSTRACT

Assessing the academic capabilities of students should play a key role in both stimulating their learning process (formative assessment) and in the accurate evaluation of their knowledge and capabilities in relation to a topic (summative assessment). Therefore, according to the principle of constructive alignment, any form of assessment needs to be carefully designed to match the learning outcomes of a course and needs to be delivered in an appropriate format (paper-based vs. computer-based) and graded in a suitable manner. However, this is a challenging task, due to the substantial amount of time teachers need to spend on grading open questions. From our experience, this results in using less appropriate assessment methods (e.g.: Multiple Choice questions) or in less time spent by teachers on innovating their courses (e.g.: implementation of formative assessment). Inspired by recent developments in academia and practice, we propose to investigate the application of machine learning technology for supporting grading of open questions, with a focus on summative assessment and exploring possibilities for formative assessment. Our expected results include the design of a method for supporting grading of open questions with machine learning, an investigation into the most suitable machine learning algorithms for small samples of tests.

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1 INTRODUCTION

Assessing the academic capabilities of students should play a key role in both stimulating their learning process (formative assessment) and in the accurate evaluation of their knowledge and capabilities in relation to a topic (summative assessment). Therefore, according to the principle of constructive alignment, any form of assessment needs to be carefully designed to match the learning outcomes of a course and needs to be delivered in an appropriate format (paper-based vs. computer-based) and graded in a suitable manner. However, this is a challenging task, due to the substantial amount of time teachers need to spend on grading open questions. From our experience, this results in using less appropriate assessment methods (e.g.: Multiple Choice (MC) questions) or in less time spent by teachers on innovating their courses (e.g.: implementation of formative assessment).

There are reasons why one type is preferred than the other. Teachers use MC rather than open questions as a final assessment because it is easy to score, provides fast grading in large classes, and can fit more questions [1]. Engineering education should engage students' abilities in independent thinking, problem-solving, planning, decision-making, and group discussion [2]. MC tends to have difficulty in examining students critical-thinking skills than open questions [3] because they just have to select the correct answer from the alternatives and do not need to formulate their own answer. Using open questions can help teachers to distinguish the level of understanding for each student from the quality of the answer.

Moreover, in open question exams, students are encouraged to prepare thoroughly and study more efficiently [4] because they are expected to answer in-depth of knowledge and a wider range of thinking [1]. The open question reveals students' ability to integrate, synthesize, design, and communicate their thought [5]. The teachers can observe whether the students achieve the objective of the course or not by inspecting how the students are applying their concepts and comprehension into a real problem.

An automated grading system can assist the teacher by reducing the grading time and enhance the learning process. Spending less time on grading enables the teachers to deliver faster feedback so that both the teacher and the students can discover which aspects the students need to improve. Several studies have been conducted in the field of Machine Learning (ML) and more specifically in Natural Language Processing (NLP) which apply to this context. On the other side, most of the studies explore how to assess short-answer questions, which requires an answer of one phrase to one paragraph and maximally 100 words [6], or an essay. However, the types of methods used in these studies are not suitable for assessing answers to open questions, which can be longer than a paragraph, but shorter than an essay. Furthermore, the analysis that is done for essays is not suitable for understanding the content of the answers since it is focused on sentence and essay structure (e.g.: word choice or grammar usage, and organization [7] rather than analysing the meaning of the answer. The main goal and contribution of this paper is to provide an alternative to existing methods based on supervised learning algorithms. We

consider that such a method would contribute to advancing the state-of-the-art on automated grading for open questions, which is an area of application for ML that is rather lacking by comparison. Furthermore, we consider that this method would help teachers by providing them with a tool which can be used to improve the process of providing feedback and grades for summative and formative assessment. Additionally, by grouping similar answers, any bias that teachers might have would be minimised as similar answers would receive the same grade.

2 METHODOLOGY

To guide the design of this research we use the CRISP-DM (CRoss-InduStry Process for Data Mining), a popular 6-step methodology used in the field of data science. We apply these 6 steps to our research as follows.

2.1 Business Understanding

The first step of the methodology refers to understanding the objectives and requirements of the organisation. In this research, several interviews were conducted with teachers from a Dutch university to identify the main requirements:

- Suitable for a smaller sample of exams (50-100 students) as most solutions are designed for large samples (500-1000 students)
- Without the need for grading a sample of exams (70-100) to train the algorithm since the exams have different questions every year
- Have control of results and transparency of the process
- Suitable for open questions
- Able to group the results based on the similarity between student answers

Based on this, the main research question was formulated: **How to design a method for assessing a small sample of open question exams with the help of ML algorithms?**

2.2 Data Understanding

This step refers to the collection and exploration of the necessary data. Our research is based on a data set which consists of 3480 student answers to 26 different questions. Each answer has information about the maximum score the student can achieve and the actual score they received (manually graded by teachers). The types of questions range from knowledge and understanding to application and analysis – according to Bloom's taxonomy [8].

2.3 Data Preparation

In this step, the emphasis is on deciding which data to include in the research and how to properly prepare this data for analysis. In our research, the most crucial step is data cleaning and preparation. Thus, to increase the performance of the algorithms the following preprocessing steps were followed:

- Removing stop words (e.g.: a, and, but, how, or, what, etc.)
- Expanding contractions (e.g.: can't – can not, shouldn't – should not, etc.)
- Removing special characters and punctuation (e.g.: !=§()%)

- Combining words with hyphens (e.g.: infor-mation – information)
- Lemmatizing the words to their base form (e.g.: went – go; going – go)
- Creating n-grams of maximum n = 3 – considering combinations of up to 3 words (e.g.: “enterprise architecture framework”)

2.4 Modelling

This step refers to making a selection of methods and algorithms which should be used for the data analysis. In the case of this research, based on the requirements mentioned in Section 2.1, one of the main requirements of teachers is to not have to train an algorithm by grading a sample of exams. The main reason for this is that the sample is not large enough for using such supervised learning algorithms. Thus, for this research, we have chosen to explore the possibility of using unsupervised algorithms. More specifically, clustering-based algorithms, such as k-means, hierarchical clustering and spectral clustering. Additionally, for feature extraction, we chose to use Count Vectorization (dictionary with all the unique words our documents contain), Term Frequency — Inverse Document Frequency Vectorizer (TF-IDF - vector representation of textual data), and Word Embedding (semantic relationships between words by having “similar” vectors for similar words).

2.5 Evaluation

In this step, the goal is to assess the performance of the chosen model(s) in relation to the business requirements. In this research, we discuss the results of applying the methods and algorithms described in Section 2.4, from the perspective of the requirements defined in Section 2.1.

2.6 Deployment

In the last step of the CRISP-DM, the plan for implementing the results of the research should be detailed. Thus, we explain the limitations and recommendations for future work based on the results we have obtained in this research.

3 RESULTS

In this chapter, we conduct an analysis of our dataset and discuss the results we have obtained by using different ML methods.

3.1 Clustering with K-means without a reference answer

First, we analyzed the distribution since we want the scores of the answers to have a reliable clustering. The goal is to distinguish between good and bad answers; therefore we need both in a reliable quantity. After choosing a suitable question we vectorized the preprocessed student answer with TF-IDF: for the parameter we chose min_df=.0025, max_df=.1, ngram_range=(1,3). Because it seems to be a good configuration for this task and we want to include n-grams. After that, we applied the k-means cluster implementation from the Python Scikit-Learn library. For the number of clusters, we started with a high number (n=10) because initially there were 10 different scores possible. We applied this further and with each iteration, we

decreased the number of clusters until n=4. Less than 4 would not be reasonable and therefore we defined it as the lower limit of clusters.

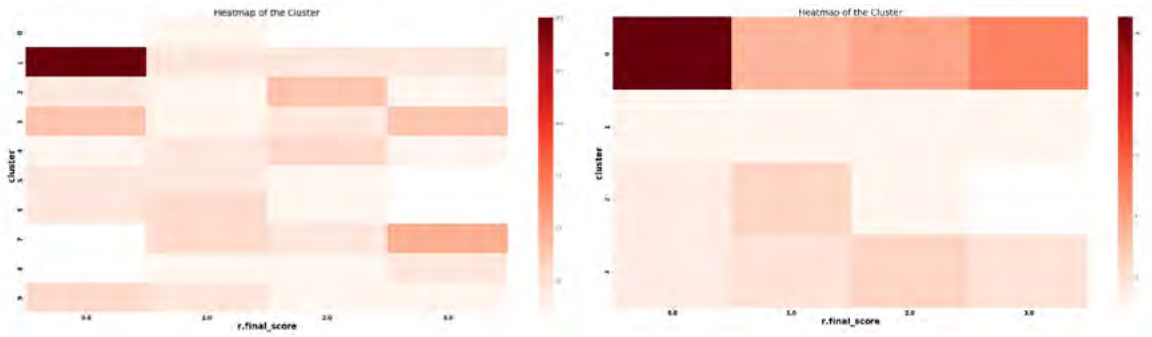


Fig. 1. Heatmap and Cluster Details for n=10 (left) and n=4 (right)

The results in Fig. 1 indicate that k-means in this configuration doesn't seem to be beneficial. There is no pattern observable and all scores are distributed over the different clusters. Additionally, regardless of the number of clusters, there is one cluster which contains a large number of answers (depicted in dark red in Fig. 1), while the rest contain much fewer answers. Therefore, this approach doesn't seem promising. One reason could be that it lacks in terms of semantics due to using a vectorizer based on the Bag-of-words approach. Therefore, we decided to experiment with several text similarity methods which could address this issue.

3.2 Similarity Analysis

The common approach for finding similar documents or sentences is based on counting the number of occurrences of similar words between sentences. This approach, however, fails to consider the fact that while the number of common words in documents increase the topics can be completely different. Here the cosine similarity helps to fix this flaw. Rather than just counting the words and calculating the Euclidean Distance, the cosine similarity calculates the angle between two vectors in a multi-dimensional space. To facilitate automated grading, not only the similarity between the student answers is important, but also the similarity between a student answer to a reference answer (provided by the teacher) is important. The reason behind this is that we expect to provide a grading system when analyzing how similar the student answer is to the expected reference answer from the professor. Based on the literature review, in the next sub-sections, we present the most promising and well-performing metrics to analyse the similarity between text.

3.2.1 Cosine Similarity with TF-IDF Vectorizer with Reference Answer

In a first step, we implemented a basic similarity analysis. The cosine similarity was simply based on a comparison between the reference answer and each student answer. Each of the answers was vectorized and the cosine similarity was calculated for each of the answers. Based on the given data we calculated the cosine similarity with the function linear_kernal and used the tfidf-vectorizer. The performance is shown in Fig. 2. As can be seen, there seems to be a correlation between the

cosine similarity and the final score. We did this analysis with more than one question and the results show a similar relationship.

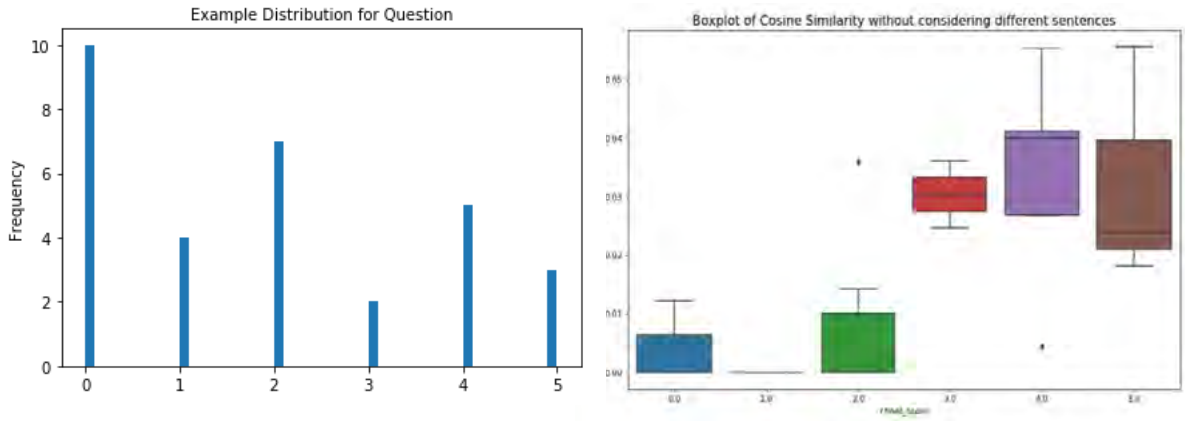
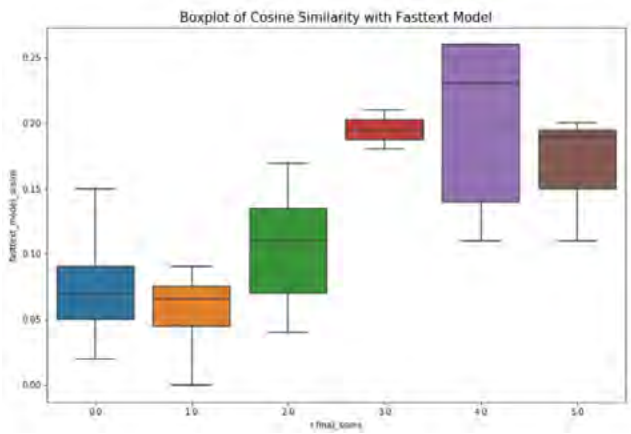


Fig. 2. Distribution of the actual scores (left) and Boxplot analysis of TF-IDF vectorizer (right)

This indicates that there is a distinguishable separation between the good (≥3) and the bad (<3) scores. Thus, this can also be used as a way of clustering the answers according to their similarity to the reference answer into 2 groups. However, if we want to further cluster the data, we have to choose a different approach.

3.2.2 Cosine Similarity with Word Embeddings with Reference Answer

Word embedding is important for the similarity measure of soft cosine similarity because student answers can address the same topic in different ways (by using different words, etc). Therefore, it can be advantageous to consider the semantic meaning of an answer as well as word similarities. The soft cosine similarity treats words with similar meaning alike by redirecting the word vectors. For getting the word vectors one needs an embedding model which can be trained on different data sets. In our research, we have used the Fasttext model which seems to be able to distinguish between good and bad answers quite reliably.



r.final_score	mean_cosine_similarity	number_answers
0.0	0.075556	9
1.0	0.055000	4
2.0	0.104286	7
3.0	0.195000	2
4.0	0.200000	5
5.0	0.166667	3

Fig. 3. Analysis of the Fasttext Embedding

The analysis in Fig. 3 shows that in general bad answers have a small similarity with the reference answer, whereas high score answers (4 and 5) have a large similarity, with some exceptions. Therefore, the result indicates that a binary cluster into bad

answers (0-3 points) and good answers (3-5 points) could be beneficial. However, we still have a certain level of inaccuracy because of outliers.

3.2.3 Cosine Similarity with Word Embeddings without Reference Answers

The literature we investigated indicated that hierarchical clustering could be beneficial since it is a bottom-up approach. The goal is to cluster those answers which are most similar. This is done pairwise and after the two most similar are obtained, the next closest answer to the previous answers is found. This is done until all the answers are grouped to one big cluster.
Since we obtained good results using word embeddings we continued using the Fasttext model for this task as well. We implemented the Agglomerative Clustering class from the sklearn.cluster Python library. The number of clusters is initially set to 10 while the parameter affinity is set to "cosine" (distance between the data points). Finally, the linkage parameter is set to "complete", which uses the maximum distances between all observations of the two sets. These default parameters are chosen using a manual parameter search. However, a more expressive study might be beneficial to optimize cluster performance. As part of this research, we want to identify a preferable number of clusters per question. We achieve this by simply decreasing the default number until 4 clusters are reached. This is chosen because fewer clusters seem to have diminishing performance.

agglo_clustering	final_scores_mean	final_scores_list
0	1.000000	(0, [1.0, 1.0, 1.0])
1	1.750000	(1, [2.0, 2.0, 2.0, 1.0])
2	3.800000	(2, [3.0, 3.0, 3.0, 5.0, 5.0])
3	2.666667	(3, [3.0, 2.0, 3.0])
4	5.000000	(4, [5.0, 5.0, 5.0])
5	2.333333	(5, [3.0, 2.0, 2.0])
6	2.000000	(6, [2.0, 2.0])
7	1.666667	(7, [2.0, 2.0, 1.0])
8	4.200000	(8, [5.0, 5.0, 5.0, 3.0, 3.0])
9	1.000000	(9, [1.0])

agglo_clustering	final_scores_mean	final_scores_list
0	1.307692	(0, [1.0, 1.0, 2.0, 1.0, 1.0, 1.0, 1.0, 1.0, 2.0, 2.0, 1.0, 2.0, 1.0])
1	1.600000	(1, [1.0, 2.0, 2.0, 2.0, 1.0])
2	2.250000	(2, [1.0, 3.0, 2.0, 3.0])
3	3.000000	(3, [3.0, 3.0])
4	1.666667	(4, [1.0, 2.0, 2.0])
5	2.333333	(5, [3.0, 1.0, 3.0])

Fig. 4. Hierarchical Cluster analysis with 10 clusters (left) and 6 clusters (right)

It seems that a high number of clusters is good when the answers are quite diverse in terms of content. Furthermore, by decreasing the number of clusters the algorithm still captures the differences well. This can be seen that the contained answers in the cluster are most of the time either 3 and 5 or 1 and 2.To understand the clustering behaviour we have analysed the student answers in greater detail (based on the results with 6 clusters – right side of Fig. 4). As can be seen in Fig. 5, all the answers in Cluster 2 are using similar wordings (e.g. Volvo Car, innovation, orchestration). However, the meaning of the sentences differ which results in different scores (answer 3 - 0.9/3.0, answer 16 & 23 - 3.0/3.0, answer 17 - 1.5/3.0).

3 The Volvo Car innovation requires a good focus on as much feedback as possible.
16 For the Volvo case, the Orchestration layer is the most appropriate to manage innovation and new product development among external innovations.
17 Most appropiate one for Volvo Car is the fact that innovation agencies are more distributed with them being formed by people with different backgrounds with no head person commanding.
23 The most appropiate logics to deal with the digitation of innovation for Volvo would be Orchestration.

Fig. 5. Detailed Analysis of Cluster 2

A similar situation can be observed in Cluster 5 (Fig. 6) where most of the words contained in the answers are similar, with some exceptions. From these results, we can conclude that the words which are common between the answers have a high impact on how the results are clustered together. Therefore, in certain situations, the algorithm can cluster together answers which do not belong together semantically.

6 Orchestration is the most appropriate for Volvo Car.
19 For Volvo Car it is most appropriate to think out of the box
24 Orchestration is the most appropriate for Volvo car

Fig. 6. Detailed Analysis of Cluster 5

We performed the same analysis by using Spectral clustering, and the results were fairly similar. The main difference is in how the method itself does the clustering. Namely, spectral clustering aims to divide data points into groups, where each point in a group is similar to other points in the group and dissimilar from points in other groups. The intention behind this approach is to try to minimize the distance between data points inside a cluster while “maximizing” the differences between data points of another cluster. This approach is useful when the data has special properties.

4 CONCLUSION AND DISCUSSION

In this paper, we aimed to propose a method for assessing open question exams with the help of ML which can be used for a small sample. To demonstrate how we achieved this goal, we refer to the requirements stated in Section 2.1.
To have a solution that is suitable for a smaller sample of exams (50-100 students) and to remove the need for grading exams to train a ML algorithm, we have chosen to explore several unsupervised learning methods (K-means, Hierarchical Clustering and Spectral Clustering). From these three methods, the last two seem to outperform K-means. Additionally, we have tested whether clustering based on similarity to other student answers or the reference answer has an impact on the results. In general, it seems that looking only at the similarity between student answers can yield similar if not better results. Thus, if the method doesn’t need to provide actual grades, but rather just a grouping of student answers that the teacher can manually grade, then not using a reference answer is beneficial. Additionally, from our interviews, it resulted that in many cases, teachers cannot formulate a reference answer which contains all the possible correct answers. This is especially the case at the master level where the questions are predominantly on application and analysis. Thus, in this situation, using reference answers would not be feasible.
Another requirement from teachers was to have control of the results and transparency of the process, while the answers should be grouped based on similarity. With our proposed method, the teachers would be able to see which

answers were grouped and can determine if their similarity is sufficient to provide the same grade and feedback. If this is not the case, then adjustments to the clusters can be made. Further details about this are available in the next section.

4.1 Limitations and Future Work

One of the main limitations of using a clustering-based method is that it cannot be fully automated. Human input will always be needed to do the grading. However, this seems to be in line with the expectations of teachers which mentioned that they would not easily trust a solution which does not require their intervention. Second, while the clustering-based methods we used showed that we can provide reasonable performance when grouping similar answers, there are still situations in which answers are included just because they share common words, while semantically they don't belong in that cluster. One solution for future work would be to remove the words that belong to the question (e.g.: Volvo car, innovation) from the answer since students tend to use these words in their answers to be more related to the question. Thus, the same preprocessing steps applied to the answers can be applied to the question and the resulting words can be used as an exclusion filter for the answers. Third, our research has included a relatively small sample of questions and answers. To further test the viability of this method, future work should include a larger sample from several exams, from both the master and the bachelor levels. This will help determine whether certain question types are more suitable for this method and whether certain topics perform better with particular ML algorithms. Additionally, future work can experiment with standardising open questions formats to make them more structured and perhaps more suitable for ML algorithms. Fourth, we have used only a small selection of available methods, algorithms and features with a limited variety of parameter adjustments. In further research, we advise using methods such as Grid search for hyperparameter tuning, and to include more features, such as Word count, Word length average, Token-based similarity, Sequence-based similarity, etc. This would help improve the performance of the algorithms since it improves their capability to capture the semantic meaning of student answers. Additionally, more advanced word embedding models such as Google's BERT and OpenAI's GPT-2 should be tested since they might be more suitable than Fasttext. Alternatively, a custom word embedding model, based on BERT and GPT-2 can be developed to include more domain-specific terminology.
The results of this research are currently used to develop a web-based tool which will include a user-friendly interface. This will allow the teachers to run the analysis of student answers based on the proposed methods, adjust the clusters to make them more uniform, and to provide grades and feedback to a whole cluster of student answers. We intend to test this prototype by using exams from multiple courses and report on the results in a future paper. The teachers involved in these courses will be asked to compare the results of using the tool to manual grading. This would allow us to assess the performance of the tool and make decisions about improving the underlying algorithms. A future goal for this prototype is to use it for supporting teachers with formative assessments by reducing the time spent on this task.

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HOW TO SCALE UP AN ACTIVE LEARNING DESIGN FROM 50 TO 500 STUDENTS

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Conference Key Areas: *Physics in engineering, Future engineering skill*
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ABSTRACT

Over the past decade student active learning sessions have been an integrated part in some of our basic physics courses. We have used innovative learning spaces with up to 15 group stations, where each station is equipped with an interactive whiteboard connected to a computer. The students work collaboratively with both practical and theoretical exercises, using the interactive whiteboard as a joint focus. As a result of this working method the teacher has an easy access to the learning process. This kind of learning design may work well,when one teacher and an assistant facilitate the activity for 50 students. Increasing the number of students to 500 represent a challenge which may inhibit teachers to plan active learning sessions where guiding and supervision is needed.

In this paper we share how we have gone from providing weekly active learning sessions for 50 to now 500 Bachelor of Engineering students. A collaboration between four teachers and eight teaching assistants made it possible to arrange these sessions for 500 students in addition to lectures without work overload. We will describe how the teaching assistants are trained and how they take part in the design of the exercises, a context which we believe is a key element. The students were asked for their perspective on the active learning sessions in an online survey, the results of which we will share and discuss.

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1 INTRODUCTION

The objective for using active learning as a teaching method is to have students actively taking part in constructing their own knowledge. In a definition given by Prince: *"The core elements of active learning are student activity and engagement in the learning process"* [1, p. 223], he states that active learning may refer to student activity and engagement during more traditional lectures, as a tool to prevent students from becoming passive receivers of knowledge. A more common way of implementing active learning is through collaboration, where the emphasis is on student interactions rather than learning individually [1].

We use the term active learning sessions to describe sessions where students work collaboratively and thereby learn together. To facilitate collaborative group work, innovative learning spaces with several group stations are used. Each group station is equipped with a large interactive whiteboard. The whiteboard supports and creates a joint focus for the learning process, where the dialogue between the students is essential [2,3]. To facilitate for this, the students' tasks are designed especially for this purpose [3].

An improved understanding of concepts is enhanced through hands-on activities, as Minner et. al. says: "*having students actively think about and participate in the investigation process increases their conceptual learning. Additionally, hands-on experiences with scientific or natural phenomena also were found to be associated with increased conceptual learning"* [4, p. 493]. To have an active learning session in a lecture hall or in an ordinary classroom is possible, but to have a dedicated space that is designed for interaction and collaboration is an advantage.

The first innovative learning space at our institution was built in 2010 [5]. To support and guide the students a teacher was always present during teaching activities in this room. As long as the number of students was low, it was possible for a single teacher to manage this alone with the help of an assistant. Previously the teacher designed the exercises alone without involving the assistant. This resulted in the assistant taking a passive role during the active learning sessions, limited to answer specific questions and avoiding deeper discussions with the students.

For larger groups of students, teachers have until now refrained from having active learning sessions due to limited time and space. To increase the number of students to 500 we found it crucial to involve more teaching assistants. Based on our previous experience it is important to have enough supervisors available who also have an ownership to the exercise and can engage in discussions with the students. This led to a teamwork between four teachers and eight teaching assistants, three teachers were responsible for the lectures, while the fourth teacher and eight teaching assistants were involved in the student active learning sessions.

2 BACKGROUND

In the spring term of 2020, weekly active learning sessions for 500 students were arranged for the first time; this represented a significant up-scaling. Because of limited capacity in the innovative learning space, the 500 students were assigned to ten different time slots. Two teaching assistants were present in each of the sessions, and the 50 students were divided into groups of four to five students. In addition to the two teaching assistants the teacher responsible for the active learning sessions was usually present. The sessions were held in the innovative learning space shown in Fig. 1:

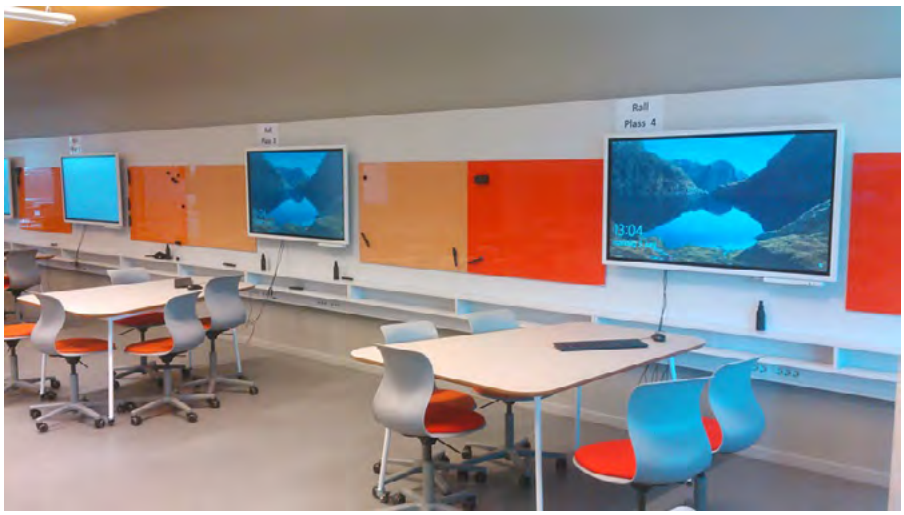

Fig. 1. The innovative learning space.

The space is equipped with several group stations, where each station has a large interactive whiteboard which is connected to a computer [5]. Here the exercises are distributed, the students do measurements, analyse data, and they write by hand on the interactive whiteboard. As well as creating a joint focus for the collaboration, the interactive whiteboard gives the teaching assistants and the teacher an easy access to the learning process [3].

The exercises consisted of practical and theoretical tasks, as well as conceptual questions for discussion. The practical exercises, as mentioned before, were developed in collaboration between the teacher and the teaching assistants during weekly meetings. Based on previous experience from active learning sessions, the teacher presented a topic and possible measurements as an inspiration and a starting point. Under guidance from the teacher, the teaching assistants engaged in a brainstorming on what to measure and how to do it. They were working hands-on using a method of trial and error, doing measurements, discussing and considering different learning aspects. To support the process the teacher asked open-ended questions. In this manner the exercise was developed, and the assistants were at the same time prepared for the discussions and questions that would likely come up during the active learning sessions. Indirectly they had also seen how to support the students by asking open-ended questions when guiding them in the learning

process. Drawing upon the experiences from this session the teacher wrote the final exercise.

The topic of the practical exercises was chosen to complement the theoretical ones by enhancing important concept and by focusing on parts of the curriculum where hands-on activities is associated with a better understanding of the physical concepts [4]. To facilitate for use of the interactive whiteboard as a joint focus, space was left open in the exercise-file for the students to share their measurements and results [3]. In the practical exercises the students had some degrees of freedom in how to do measurements and how to present the results. This is in line with the goal of increasing student engagement and interaction.

3 METHODOLOGY

To evaluate the active learning sessions an anonymous questionnaire was distributed to all students. The students were asked about how satisfied they were with the active learning sessions, indicated on a scale from 1 (not satisfied) to 5 (very satisfied). In addition to the purely quantitative response, the students were encouraged to write their qualitative perspective. The students' comments have been read by all authors through several iterations in order to agree on the interpretation and obtain a consistent view of the results. Comments included in this paper are translated into English by the authors. In total 112 of the 512 students participated, which corresponds to 22%.

4 RESULTS AND DISCUSSION

The numerical results of the questionnaire show an average of 3.7 concerning students' satisfaction. There are some differences between female and male students, while the female students are less satisfied with an average of 3.3, the male students have an average of 3.8. Fig. 2 shows the total distribution of student satisfaction:

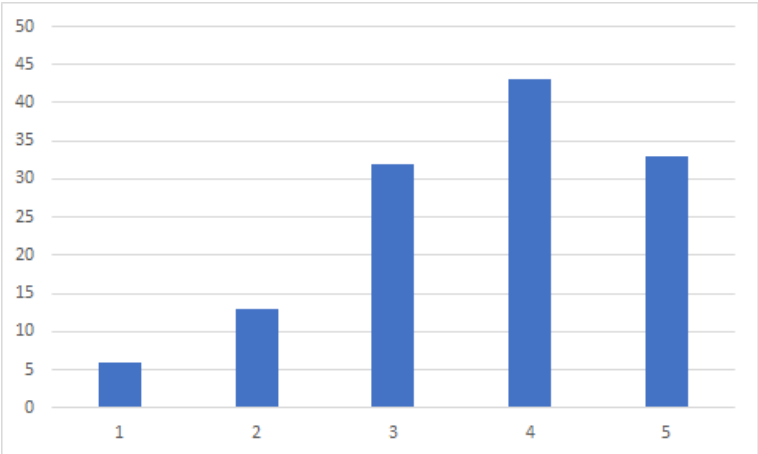

Fig. 2. Number of students versus degree of satisfaction with the active learning sessions. Satisfaction on a scale from 1 to 5, where 1 is not satisfied and 5 is very satisfied.

Overall, the result shows a high degree of student satisfaction among the 112 students which answered. However, a deeper insight into students' perspective is revealed in the written comments, which we present in the following.

The purpose behind having the students collaborate and work in groups, is to encourage students' interactions. The group-work has more benefits than learning physics, as stated by this student: "*[It] creates a good learning environment where everyone (who wants) can engage".* The possibility to collaborate is acknowledged: *"It is nice to have the opportunity to collaborate, 'the effort was rewarded' ".* Compared to other courses where the students worked individually, the group-work was rather unique.

Regarding the more traditional exercises in other courses, the main focus is on finding the right answer. In the active learning sessions this is not the case: *"... when we're a group we learn from each other, no one copies answers".* For several reasons copying answers is not an issue in the active learning sessions as the focus is on procedure and discussion. Each group produces their own measured values and thereby their own results. If a group needs support, the teaching assistants are there as supervisors.

An important aspect when preparing the teaching assistants for the active learning sessions was how to support and help the students. As a student pointed out: *"The teaching assistants have been very good and helpful. They have not only told us the answers if we were stuck, they "are working with us" to find the solution*." It is also our observation, that the teaching assistants were more active compared to earlier courses. Since the teaching assistants now take part in the design process and have already discussed the exercises, they have gained insight into thoughts and considerations concerning the assignments. We think the teaching assistants feel an "ownership" to the exercises. Through the involvement in the design process they have learned how to support the learning process themselves, by asking open-ended questions. In addition, the teacher was also supervising the students in the active learning sessions, and thereby kept acting as a role model for the teaching assistants.

Regarding the practical hands-on activities students recognise this part as valuable or even crucial for learning the concepts: "*It is a good arena for discussion, and you "see" theory through practice".* Another student says: *"It is good to collaborate and discuss physics together, and to have practical elements that increases the understanding. However, it is difficult to go through many tasks in such large groups and one can therefore argue whether it is more effective to have individual exercises. You might get more done (tasks) in this way".* This general acknowledgement of the hands-on activities as important to increase conceptual learning is in-line with the findings in [4]. However, several students claim that they would prefer to work individually, since they feel this is a more effective way of working. The wish to work

alone might arise from the fact that this is the working method they are used to from other courses and from a belief that doing a lot of exercises gives more learning than working deeply with a few.

A related aspect mentioned by the students was the workload of the exercises. Some students were overwhelmed by the number of tasks. The intention behind the exercise was not to have the students completing all the tasks during the active learning session, but rather encourage them to focus on learning and deeper discussions. If they did not finish the exercise, they were encouraged to complete it afterwards. However, this resulted in stress for some students: *"Unfortunately, there is a time pressure to get through exercises during the session, therefore, we do not spend time discussing well enough and include everyone in the group. Physics is a subject that takes time to learn and get used to, so stressing through the exercises is not a very efficient way to learn"*. It seems, that we have not communicated well enough our intension behind the active learning sessions.

The purpose of the active learning session is for the students to learn together and construct their own knowledge. Timing is therefore important and the weekly exercises should be planned accordingly to the lecture plan, as pointed out by this student: *"*[The exercise] *was about the theme we just had* [in the lecture]*, something which made us work faster with new topics".* It is an advantage if the lecturer can relate to the activities both in the lecture before and after the active learning session. With 500 students and a space limitation of 50 it is an administrative challenge to have a well-planned time schedule for all students. Ideally the content from the active learning session should naturally fit into the theme of both the previous as well as the following lecture. This only works if all groups attending the course have their active learning sessions in between two following lectures.

We noticed that for some groups the collaboration was more difficult. Behind the average of satisfaction of 3.7 we received comments suggesting why some students are less satisfied. Comments from shortly "*I hate my group"* to the more descriptive "*The group assignment does not work, those who know – do it".* There are several reasons that can explain this, one is keeping the same groups throughout the semester. Previously, in smaller courses, we have changed groups every week, in order not to let the groups develop "bad habits". However, the learning management system (which is mandatory to use) does not easily allow new groups for every session. We were aware of this before starting up, however the logistics around a manually registration of 500 students each week made us go for fixed groups.

5 CONCLUSIONS AND FURTHER DEVELOPMENT

To scale up an active learning design from 50 to 500 students, and still be able to support the groups during the sessions, it is crucial that the number of supervisors is scaled up as well. To do so we found it necessary to engage teaching assistants in addition to the teachers involved. Based on our experiences we acknowledge the

importance of having supervisors with an ownership to the activities. In the next run of the course it is therefore important to have the teaching assistants involved in the same way as we did now, having them engaged in developing the practical exercises.

For further improvements a better alignment between lectures and active learning sessions is preferable. This might be achieved by introducing and later giving a closure of the active learning session as part of the lectures. Another improvement is to emphasize the importance of problem solving through collaboration and discussion as an important part of practicing future engineering skills. This is something that we must communicate more clearly to the students.

6 ACKNOWLEDGMENTS

We appreciate the response from the students, providing us answers in the questionnaire.

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DESIGNING GOOD PRACTICES FOR TEACHING AND MANAGING MULTI-CAMPUS COURSES

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Conference Key Areas: *Engineering curriculum design, challenge based education, maker projects, use of professional tools.*
Keywords: *Curriculum design, multi-campus courses, culture for collaboration*

ABSTRACT

In 2016, our university college merged with several other educational institutions to form a multi-campus university. Mergers and clustering of universities have been a European trend over the past decade, and although the trend has now flattened out, such restructuring processes are still ongoing. In the wake of mergers follows a restructuring at many levels. Teachers involved in the Bachelor of Engineering education at our multi-campus university faced the challenge of developing and aligning courses for 1000 students across three different campuses located far apart.

The Department of Physics is responsible for a first-year introductory course in physics and chemistry, which is mandatory for all Bachelor of Engineering studies: 11 study programs under four different faculties in three cities. A team of nine physics and/or chemistry teachers deliver the course to students, most of whom are on-campus students while a minority follows the course online. In this paper we focus on experiences from the teacher collaboration, involving the preliminary design process and the practical implementation of the course during the spring term of 2020 before the COVID-19 outbreak. The students were asked for their perspective in an online survey, the results of which are reported and discussed.

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As a result of the collaboration between the nine teachers at three campuses, all teaching resources used in the course are made available to teachers and all enrolled students across campuses – an approach much appreciated by the students. This open, full-access approach shows, that even though the teaching material was harmonized in the preliminary phase, teachers are presenting the same topic somewhat differently. This gives room for further development and collaboration.

1 INTRODUCTION

Mergers and clustering of universities have been a worldwide trend over the past decade, and in Europe there was a peak between 2013 and 2015. Although the rate is now decreasing, such restructuring processes are still ongoing, e.g. in France, Lithuania and Greece [1].

In 2016 our multi-campus university was formed as a merger between a larger university (Norwegian University of Science and Technology) and three smaller university colleges. One of the overall intentions behind the merger of the four institutions was to provide a better and more comprehensive education of high standard [2]. Case studies from Northern Europe have identified similar rationales behind mergers in other parts of the world: a desire for efficiency and effectiveness. However, in the Nordic countries, arguments of better quality and excellence of education tend to carry heavier weight [3]. When it comes to the degree of integration between the merging institutions it depends of the purpose behind the merge. Some "*...mergers are more "federal" by character with the merged units remaining largely intact yet within part of a much larger organisation. Arguably, in the short term, these mergers are easier to manage and implement but with less obvious added value for the parties involved. Other cases display a high ambition from the outset"* [3, p. 231]. In our university we see both aspects represented, the government wanted to reduce the number of institutions in higher education, while the actual merge however showed a wish for integrating the four institutions into a new institution [2]. Geschwind et. al. [3] also points out that the distance between the campuses and cultural differences can play a crucial role regarding the success of the merge. The geographical obstacle is an obvious challenge in our case, while cultural the teachers involved in the Bachelor of Engineering programs have a lot in common since they all came from the university colleges.

2 BACKGROUND

Before the merger, the three university colleges were located at separate campuses in cities 300-400 km apart, corresponding to a car drive of 5-6 hours – as illustrated in Fig. 1. The teachers involved in the Bachelor of Engineering education at our multi-campus university therefore faced the challenge of developing and aligning courses for approximately 1000 students across three different campuses located considerable distances apart.

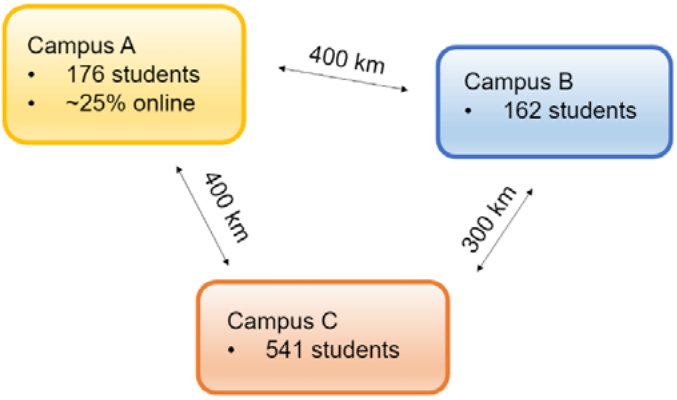

Fig. 1. The three campuses, separated by distances of 300 to 400 km.

The Department of Physics was responsible for restructuring a mandatory first-year introductory course in physics and chemistry for all 11 Bachelor of Engineering study programs, representing four different faculties in three cities. A substantial amount of the students has a vocational education background, requiring one- or two-semester qualifying courses before starting an engineering education. At Campus A and B, some of the students take qualifying courses in parallel with engineering studies, while campus B and C offer qualifying courses which are not part of the Bachelor of Engineering studies. Before the merger, the first-year introductory course in physics and chemistry was delivered identically to all study programs at campus A and B, whereas campus C had five slightly different courses, tailored to specific study programs. Campus A was unique in offering courses for online students as well as on-campus classes.

The design of the new course thus had to take into account differences in students' educational backgrounds; offer study program-specific learning modules; and make allowance for both on-campus and online students. These requirements translated into the following modular course structure:

- Common chemistry module (2,5 credits): Atomic structure and the periodic table, stoichiometry, chemical equilibrium, acids and bases.
- Common physics module (5,0 credits): Classical mechanics, rotational dynamics, oscillatory motion.
- Study program-specific modules (2,5 credits):
    - Fluid mechanics and physics of waves (for students of building engineering and mechanical engineering).
    - Electromagnetism (for students of electronics; renewable energy; logistics engineering; materials engineering; chemical engineering).

The chemistry module is common to all study programs except materials and chemical engineering, for whose students the chemistry module consisted entirely of electrochemistry. The new course is offered at campuses A, B and C in 3 different module combinations, with identical expected learning outcomes and a final exam with the same classical mechanics part.

3 METHODOLOGY

3.1 Course predesign – developing a culture for collaboration

The alignment of the first-year course in physics and chemistry was a part of a unification initiative for all Bachelor of Engineering study programs at the three previous university colleges, also involving mathematics courses and an Introduction to engineering course. This process culminated in draft versions of the relevant courses, based on input from the Bachelor of Engineering study programs.

The three university colleges had a similar academic tradition and culture in terms of course content and approach to teaching, which facilitated the alignment process. Despite geographical distances and lack of convenient travel routes, physical rather than virtual meetings were held at each campus in turn, with both involved teachers and administrative staff in attendance.

After the start-up phase in the spring 2019, the development of the physics and chemistry course continued over the autumn term in online meetings using collaborative tools. The underpinning strategy was to facilitate a culture of collaboration, in which decisions were made through team processes, rather than unilaterally at each campus.

3.2 Resource sharing

Our university mandates the use of a specific learning management system (LMS) to manage courses. Traditionally each course has its separate “space” or virtual “room” inside the LMS, to which only enrolled students and teachers have access. Our course consists of several separate courses, each with its own coordinator. To maximize transparency for students and teachers, a shared and open “virtual room” was set up on the LMS, as shown in Fig. 2 below.

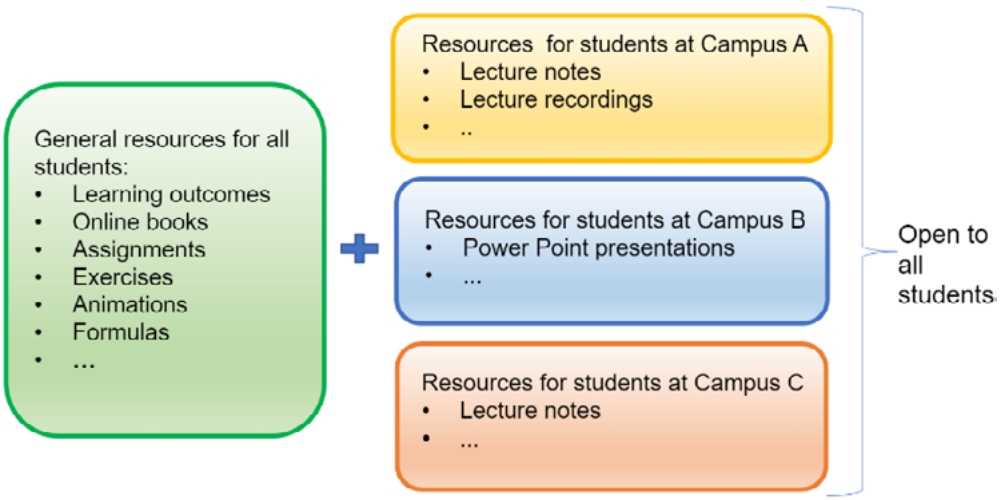

Fig. 2. The design of the resources at the learning management system.

Information common to all students is located in one folder, as illustrated by the green box. Lecture notes, presentations etc. specific to each individual course is put in folders corresponding to a specific campus to which all students and teachers at any campus have access (this illustration is a simplification since more than one version of the course exists per campus). The principle of having everything open to anyone enrolled in the course gives full transparency, which is an important aspect since learning goals and the final exams are the same across the campuses.

3.3 The questionnaire

An online questionnaire was constructed to survey student experiences with this multi-campus course, with questions based on input from all the teachers involved. The questions were intended to detect campus differences in student satisfaction with on-campus teaching, and also to map how, and to what extent, students used shared learning resources.

The questionnaire received 188 answers from a total of approx. 900 enrolled students, giving a response rate of 20 %. It was published shortly after all Norwegian educational institutions closed their campuses following the COVID-19 outbreak mid-March 2020, at which point all classes were moved online. The questionnaire specified that all questions concerned the situation before the corona virus outbreak, when on-campus classes were still running normally.

The structure of the questionnaire used is detailed below:

- Student background (study program; specific course enrolment; whether on-campus/online student; gender)
- Experiences from chemistry and physics classes, respectively
    - Level of satisfaction with on-campus classes
    - Rate of usage of shared resources and learning material available from the LMS (with answer categories of “Often”; “Sometimes” and “Never”), and students’ level of satisfaction with these resources

4 RESULTS

One item on the questionnaire concerned the usage of resources shared between campuses: lecture notes and video recordings from campus A. The rationale was to uncover the extent to which students used resources from their own lecturer and material from other lecturers/campuses, respectively. The results are summarized in Fig. 3:

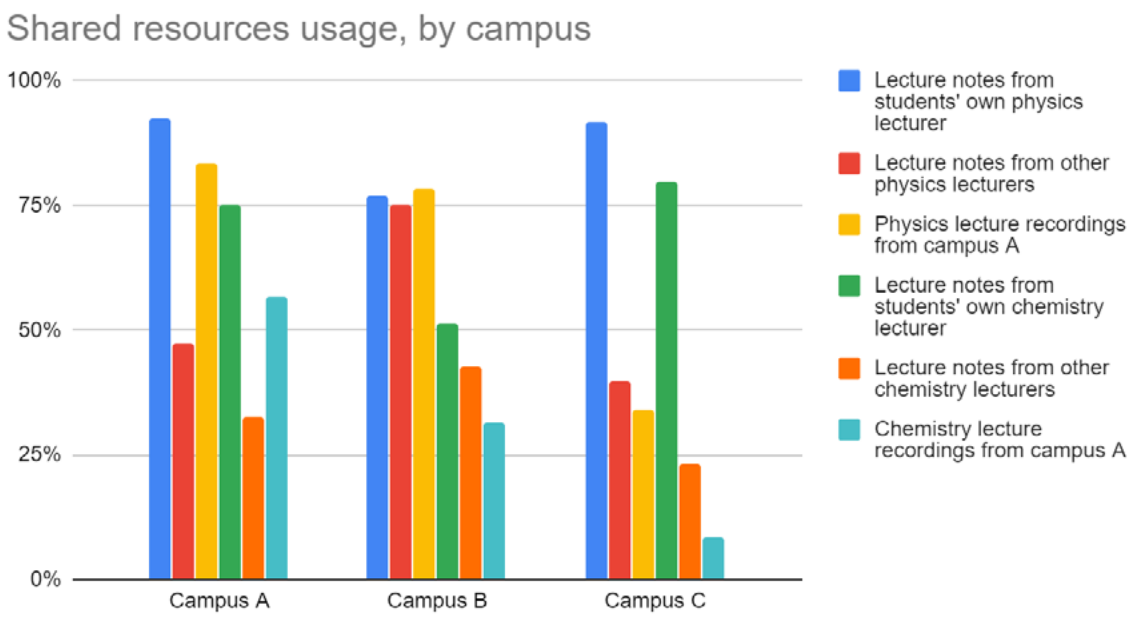

Fig. 3. Usage of different types of shared resources in physics and chemistry, by campus. Campus A produced lecture recordings to which all enrolled students had access. Percentages of students are the sum of percentages in categories "Often used" and "Sometimes used" the shared resource.

The majority of students preferred lecture notes from their own lecturer (in both physics and chemistry, the blue and green columns). The exception was campus B, where students expressed preference for lecture notes made by others. In the comments field of the questionnaire, students who preferred lecture notes from other lecturers cited language issues as one reason, as their own lecturer predominantly used lecture notes in English. Lecture video recordings were produced at campus A, and students at campus A used these recordings more than students from other campuses.

The following two comments from students illustrate perceived benefits and drawbacks of consulting study materials produced by other teachers:

- [On why he/she appreciates lecture notes by other teachers] *«Difficult to connect the dots when the textbook and PowerPoints are in English, while lectures are held in Norwegian. »*
- [On watching lecture recordings from campus A] *«Lecturers from the various campuses have different backgrounds and areas of expertise, and approach topics differently, using unique teaching styles. This makes it harder for me to follow other lecturers with whom I'm not familiar. »*
- [On why he/she appreciates lecture notes by other teachers] *«I like having access to the notes from all the lecturers, it gives you access to more examples and different explanations. »*

Regarding the general use of the LMS, some students claim that there is too much information available. On the other hand, some students appreciate the shared resources and asked for the same transparent LMS-design in other multi-campus courses.

5 DISCUSSION

Since this course was run for the first time, teacher collaboration was mostly on a practical and administrative level, as opposed to a pedagogical level. While some study materials were produced during the course predesign phase, a considerable amount of lecture notes, assignments etc. were produced continuously as the semester progressed. Time constraints limited the amount of pedagogical discussion between teachers once the semester had started.

The teachers involved had different backgrounds and areas of expertise, and the working hypothesis in the planning stage was that the diversity in teaching methodology, teaching style and approach to topics would let teachers complement each other. However, it's evident from Fig. 3 that students only to a limited extent consulted study materials made by other teachers. As indicated in a student comment, teacher non-uniformity was seen as an impediment to learning, as students take time to get used to a particular teaching style. The interpersonal student-teacher relationship appears important for making students relate to the online learning resources, as students in the questionnaire expressed preference for recordings of their own lecturer. The importance of this relationship is higher than we expected and should be addressed in the future as a potential barrier for learning when using online materials.

Given that all enrolled students would be subjected to the same exam, transparency was the main rationale for having a shared virtual "room" in the LMS. From the teachers' perspective, a shared "room" would enable uniformity and synchronization between lecturers teaching the same topics. Even though this article concerns the situation before the COVID-19 outbreak, the shared space proved very useful once all classes moved online when the campuses were shut down: The extra workload with producing study material for online teaching could be split between teachers; students had uninterrupted access to online classes and study material by other teachers; resource sharing made course delivery more robust and resilient.

For next year's course, having accumulated experience from a pilot run, the teachers involved have expressed determination to focus on teaching methodology and didactics, more than the practical considerations which invariable dominate a pilot run.

6 ACKNOWLEDGMENTS

We appreciate the response from the students, providing us answers in the questionnaire.

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DIGITALIZATION OF ENGINEERING MECHANICS PROBLEMS APPLYING THE STACK-CONCEPT

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Conference Key Areas: *E-Learning, Online-Learning*
Keywords: *Digitalization, Excercises, Homework, Engineering Mechanics*

ABSTRACT

It is widely accepted that in Mechanics and other technical courses students need to work on problems by themselves for a good learning outcome. The assignment of homework seems to be a reasonable method of making students deal with problems. The downsides are big efforts for organization and evaluation of the homework. Considering that many students simply copy their homework from fellow students, the effort seems questionable and keeps many professors from assigning homework.

Improvements can be obtained by digitalizing Mechanics problems applying the STACK-concept. STACK is a free Plug-In for electronic learning systems like Moodle or Ilias. It is backed up by a Computer Algebra System and is therefore able to interprete and evaluate mathematical expressions (matrices, equations, etc.). So far mainly mathematicians apply it for mathematical education. But STACK can generally be applied in any discipline where mathematics is involved, which is the case in most courses of engineering education.

STACK additionally contains some interesting features, i.e. can produce random numbers, so every student gets different values and is therefore forced to work on his own individual problem. Evaluation is completely done by the system. After putting in an answer the student can check his answer for correctness. Depending on his answer the student may receive an individual feedback, which can be provided by a response tree. The digitalized problems may also be extended by interactive graphical elements.

First implementations of STACK-Problems in homework assignments show promising results and good acceptance by the students.

1 INTRODUCTION

There seems to be agreement that students not only should attend the lectures but also need to work on problems themselves for consolidation of knowledge and a good learning outcome (i.e. [1]). The usual way to do so is to assign homeworks. Homework is considered to enhance student knowledge, improve retention and master concepts taught in the lectures.
To activate students working on problems, homeworks are often mandatory prerequisites for participation in the final exam or bonus points are awarded. Mandatory homework assignments are not so common in Germany compared to other European states. The main reasons for this are that

- the correction of homework is usually involved with a tremendous correctional effort and
- students often copy the homeworks from each other questioning the concept.

Still the engineering education proved to be successful over the decades since most students have been self-reliant enough to work on problems themselves without being enforced to do so.

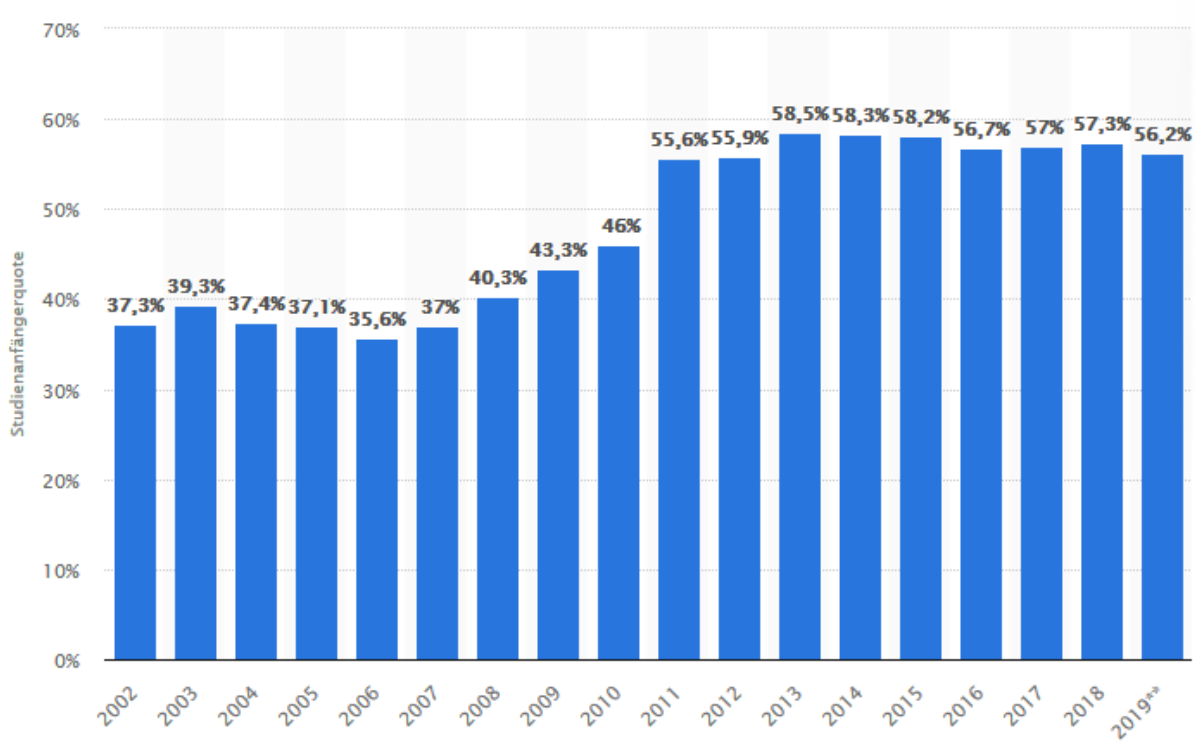


Fig. 1: Percentage of young people in Germany starting studying in their age group [2]

In the last couple of years students behavior as changed with students starting studying at a younger age and therefore less self-reliant due to political changes during the last couple of years in Germany [3]:

- In 2011 the “Wehrpflicht”, the duty of young men to serve for the military, was suspended.

- In the years from 2011 to 2013 most German regions cancelled a school year enabling students to finish school and qualify for university after 12 years of school instead of 13.

Furthermore the percentage of young people studying has increased from 37% in 2002 to to almost 60% nowadays (Fig. 1). This is especially promoted by the German industry, which is permanent seeking for young people with a good technical education, and German politics thus taking the necessary actions.
Due to these changes adjustments in teaching are recommendable to be able to better support the students. For example, university teachers should assign homework on a more regular basis. The computer aided assessment system STACK has proved to be a wonderful tool to implement online homework and make students work on technical problems.

2 THE PROBLEM-TYPE STACK

STACK is a free plug-in for electronic learning systems like Moodle or Ilias. Next to the variety of online assessments already offered it enables a completely new type of online problems. STACK stands for „**S**ystem for **T**eaching and **A**ssessment using a **C**omputer Algebra **K**ernel". It has been developed by the British Mathematician Chris Sangwin [4] from the University of Edinburgh.
In the meanwhile STACK is used by quite some universities throughout Europe and probably also on other continents. So far it is mainly applied by mathematicians in the mathematical education of students. But generally STACK may be applied in any discipline where mathematics is involved, especially in classical engineering courses like Mechanics, Electrotechnics or Thermodynamics.
What makes STACK so unique compared to previous kinds of online assessment systems is that it contains some special features with some of them listed here:

<u>Computer Algebra System</u>
In the traditional type of online-assessment students put in a string as answer which is compared to an answer string provided by the developer of the problem. Since STACK is backed up by the Computer Algebra System "Maxima" mathematical expressions like equations, matrices or sets can be put in as answer. Usually there are different possibilities how to put in a mathematical expression. A constant factor for example may be placed at the beginning or at the end of an expression. STACK doesn't care about this since it is able to evaluate mathematical equity of answer and solution.
A validation button is additionally offered, enabling the students to check, how their answers are interpreted by the system.

<u>Randomized Problems</u>
When assigning homework in Germany a common problem is, that students simply copy their solutions. Compared to states like UK or USA a thing called "academic

honour" does not exist. In Germany students often treat it as a sport to cheat the professor.
The possibility of randomizing problems by giving the students different numerical values is therefore a wonderful thing. The times, where homework results are spread in WhatsApp-Groups are gone forever. Each student gets his own individual problem and therefore is forced to deal with it and work on it.

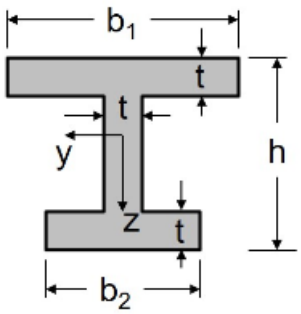
Individual Feedback
Right after putting in an answer students can check their result for correctness by applying the Check-Button and receive feedback immediately. The students may then correct their answer if it proves to be incorrect. The number of re-submission of results can be limited though.
If the result of the student proves to be false the student may also receive individual feedback depending on his answer. The feedback is provided by a response tree, which has to be created by the developer of the problem. Instructors usually know about common errors of their students and can make the system give special feedback and maybe advice to the students, which should enable them to finally solve the problem.
If a problem is partially solved students may receive partial credit.

Interactive Graphical Elements
In the meanwhile STACK-problems can be extended by interactive graphical elements. Possibilities will be shown in a later chapter.

3 APPLICATION TO ENGINEERING MECHANICS PROBLEMS

More than 100 STACK-problems were developed in early 2018 and tentatively tested in the summer-semester of 2018 in a "Mechanics of Materials"-course. The students had to complete online homework, working weekly on 3 to 5 online problems. They had to collect 80% of the maximum number of points awarded for correctly solving the problems to be permitted to participate in the final exam.
When implemented in STACK typical "Mechanics-of-Materials"-problems can usually be separated into various partial problems, which build up on each other as shown in figure 2. In this problem the students have to finally determine the maximum tensile and compressive stresses for a beam with the given profile stressed by a bending moment. The numerical values below the graph are randomly chosen from intervals by the system.
To be able to calculate the stresses, various cross-sectional quantities have to be determined first: Especially the axial area-moment of inertia needs to be known, which of course can only be computed if the location of the area center is determined in advance.
So by splitting the problem into various parts the students are kind of guided through the problem. They can right away see the steps necessary to solve it. By repeatedly doing so they get a certain routine on solving this type of problem.

TM2-Problem 3-05



A beam with the sketched profile is stressed by a bending moment of M_y = 80 kNm.

Determine the maximum tensile and compressive stresses.

Given: $b_1 = 340\ mm, b_2 = 160\,mm, h = 300\,mm, t = 30\,mm$

a) Distance of Area Center from Top Edge of Profile: ζ_S = [ ] mm

b) Area Moments of Inertia: I_y = [ ] cm^4

I_z = [ ] cm^4

c) Axial Section Modulus: W_y = [ ] cm^3

d) Max. Tensile and Compressive Stress:

$\sigma_{t,max}$ = [ ] N/mm^2

$\sigma_{c,max}$ = [ ] N/mm^2

Prüfen

Fig. 2: Typical Mechanics-of-Materials STACK-Problem

In STACK-based online problems the students can check their results after each step and receive immediate feedback by clicking the “Prüfen”(“Check”)-Button (Figure 2). If the feedback is positive (“Correct”), the student can be very sure about continuing the problem with the correct partial result, which he will need to solve the next part of the problem. If the students entry proves to be incorrect he can overwork the problem and reenter the solution until positive approval is given. The student may even receive feedback by the system as generated by the developer of the STACK-problem. Depending on the students answer the feedback can be very specific as can be seen in figure 3.

In the problem shown in figure 2 it would have been possible just to ask for the final answer which are the quested stresses. However, if students enter an incorrect final answer it might become very difficult to find out, in which part of the problem the error occurred. It is therefore much more efficient, helpful and motivating for the students to split the problem into several parts.

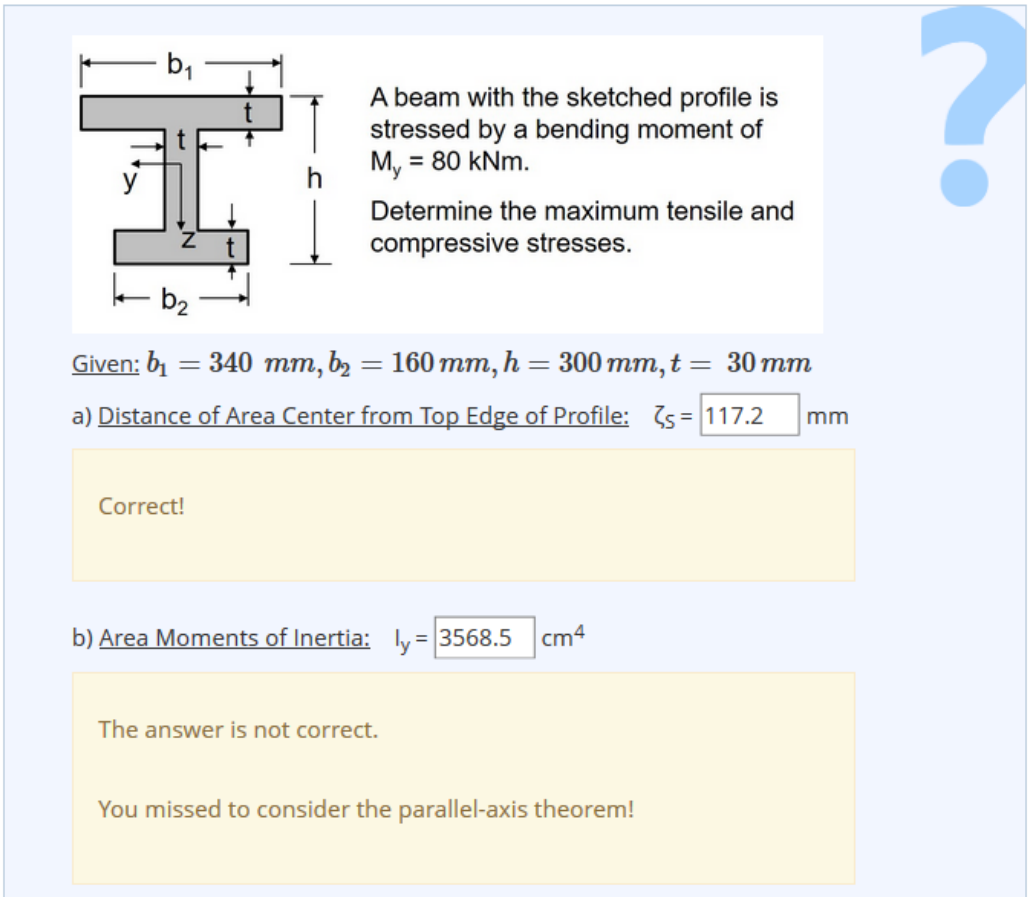


Fig. 3: Positive approval and specific feedback by the system

4 INTERACTIVE GRAPHICAL ELEMENTS

New web technologies and further development of electronic learning systems have simplified the use of interactive graphical elements in mathematical and technical online problems. By embedding JavaScript based JSXGraph-Elements STACK-problems can be expanded by interactive graphical elements, which can be developed with manageable effort [5]. JSXGraph is a JavaScript-Library, which helps to develop interactive graphics with little code and minimal programming knowledge. The graphics may be embedded on HTML-sites and displayed on all common web-browsers without additional software [6].

Graphical solutions are widely accepted to deepen the students understanding of Engineering Mechanics. Interactive graphical parts lead to a diversification of STACK-problems. Graphical methods in Mechanics are for example applied when adding forces in force diagrams in Statics or adding velocities and accelerations in diagrams in Dynamics. Instantaneous center of velocity diagrams can widen the students views of what is happening in a mechanisms. Again individual feedback depending on the students solution is possible (Figure 4).

Although interactive graphical elements are a clear enrichment for digital exercises there is need of further development. As the procedure is different depending on the

electronic learning system there should be a more standardized approach for embedding JavaScript-elements in STACK-problems. This would simplify the import and export of problems into other systems to generate a fruitful exchange between universities.

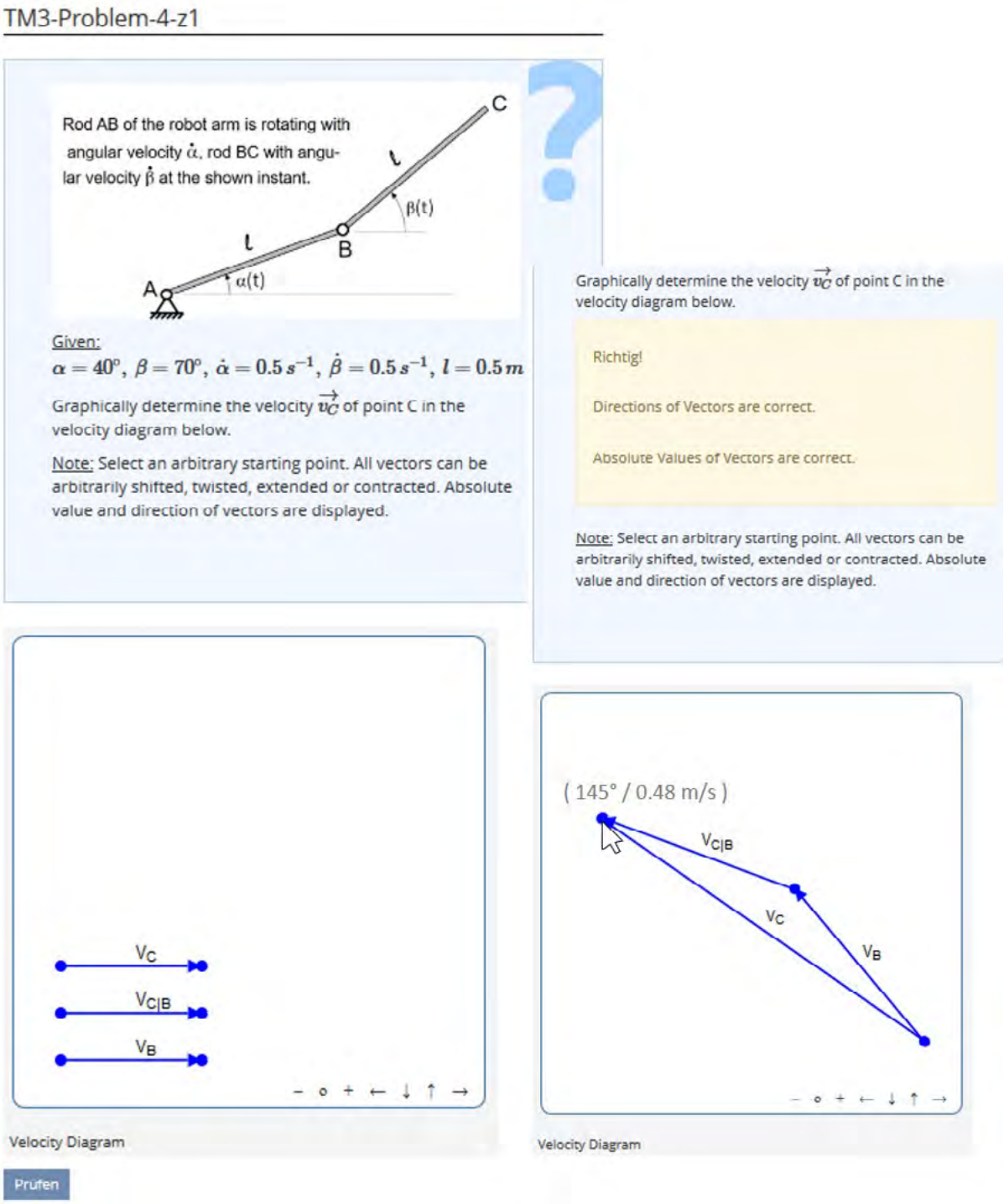


Fig. 4: Problem with interactive graphic element (left), solution with feedback (right)

5 EVALUATION BY STUDENTS

Starting back in 2018 STACK-Problems have been developed for the three common courses in Engineering Mechanics (Statics, Mechanics of Materials, Dynamics) at the University of Applied Sciences Karlsruhe. In the Mechanics of Materials course STACK-problems have been employed for four semesters, in Dynamics only for one semester so far. During the ongoing Covid-19-Semester, where no presence teaching has been possible, it has been deployed for all EM-courses.

As can be seen in figure 5 opinions are diversified with students expressing positive and also negative comments about having to work on Online-STACK-Problems. Positive voices mostly emphasized the gain because of immediate feedback and the benefit of continuous exercising. Negative comments were almost entirely because of the time-consuming aspect.

The attitude changed in the ongoing Covid-19-Semester with almost all students commenting positively about online exercises and therefore obviously recognizing the benefit.

Generally the students seem to accept this kind of online-exercise. Many young people love to play computer games, solving problems on the screen and getting awarded by collecting points. Online homework is not so much different from that so there should be motivation for this kind of exercise.

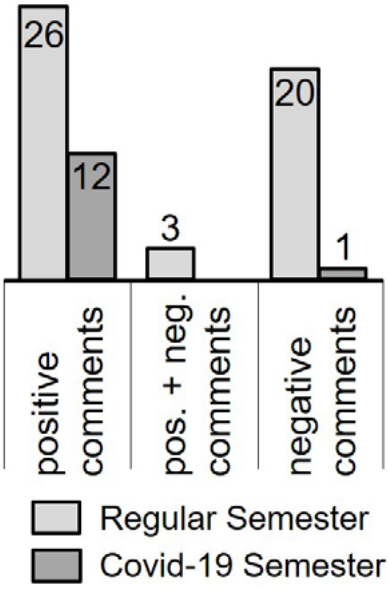


Fig. 5: Evaluation by Students

6 SUMMARY

Not only in the times of Covid-19-Virus STACK has proved to be an extremely valuable tool in the technical education especially for young students in early semesters since it has been introduced at the University of Applied Sciences Karlsruhe. New features like evaluation of mathematical expressions, individual feedback, randomized numerical values and graphical elements implemented into the STACK-concept widen the possibilities for this kind of E-learning. Positive comments in the semester-evaluation show, that the students accept this kind of exercise and see the necessity of working on problems in addition to the lecture to improve their learning outcome, although some students complained about the increase in the workload. In many technical disciplines different kind of problems can be generated for fruitful use. Interactive graphical elements contribute to a higher motivation and understanding of the students. The development of STACK-problems is time-consuming and has to be done very carefully since possible errors would only confuse the students, but the effort is well worth it.

ACKNOWLEDGEMENT

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SOCIAL INNOVATIONS IN TECHNICAL UNIVERSITIES: COMMUNITY-BUILDING – AN APPROACH

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Conference Key Areas*: Interdisciplinary engineering education, linking different disciplines both inside and outside engineering, linking with society; Sustainability and ethics, embedded and dedicated approaches.*
Keywords*: Community-Building, Science & Society, Social Innovation, Service-Learning*

ABSTRACT

There is unanimous agreement within the technical sciences on the importance of engineering for societal development. Sensitizing engineers to the challenges of our society and to inter- and transdisciplinary collaboration is important for modern engineering education. The paradigm of Responsible Research and Innovation is ubiquitous in funding agencies and research institutions as well as universities. Social responsibility is understood as the foundation for excellent research and teaching. Based on this, RWTH Aachen University understands the potential of innovative, socially responsible engineering education to meet new challenges. Therefore, the "Responsible Research and Innovation Hub" (RRI Hub) was founded in 2019, based on the concept of the integrated and interdisciplinary university.[2] The aim is to establish an extensive collaboration between science and society to find solutions to complex problems through collaboration and co-creation with and for society. The RRI Hub has therefore developed a structured community-building concept for regional and supra-regional ecosystems, which will be subject of the conference presentation. Our approach is that social innovations for complex problems can only emerge in lectures if the results are connectable. This can be achieved by involving qualified actors in the research, development and teaching process. In a multi-stage community-building process, actors were identified,

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contacted and systematically integrated. Frequent communication with partners inside and outside the city has led to trustful collaborations from which both science and society benefit. We show how a successful community-building approach can look like and which challenges universities have to face in such processes.

1 INTRODUCTION

In the 21st century our society will face several ecological, economic as well as social challenges. Finding solutions for these challenges is crucial. As the actual COVID-19 pandemic drastically demonstrates these challenges formulated within the Sustainable Development Goals (SDGs) are interfering and interacting in many dimensions [1].

Universities contribute significantly to the development of new innovations through their research and have a high innovation potential as the ranking of "Europe's Most Innovative Universities" shows [2]. These innovations are supported on the one hand by public funds of the government and on the other hand by industry-led third party funds. Successful innovations resulting from collaboration between universities, industry and government show what a successful technical innovation ecosystem can look like. The collaboration between these actors enables the development of innovations designed to meet the needs of the stakeholders involved.

But as formulated within the Responsible Research and Innovation (RRI) concept, technical innovations have to be developed with stakeholders from society in order to develop sustainable solutions that include ecological, economical as well as social perspectives. RRI's rationale is "that science and technology have the power to transform the future, that they are socially, ethically and politically entangled and that they can have potentially far-reaching, uncertain and unpredictable social consequences" [3]. Therefore, engineering sciences for example have to collaborate with scientists from other disciplines and with the involvement of society in order to create solutions that meet the needs of society. Various scholars state that social innovations can contribute to solving global challenges. Especially in the case of social innovation, collaboration with different actors and society is necessary [4]. The development of a social innovation ecosystem is essential and existing technical innovation ecosystems can be used as a starting point for their development. However, various innovation models as the triple helix model fail to take civil society into account [5]. We argue that civil society as a driver of social change must be considered and involved in social innovation processes. In order to promote social innovation, universities need to develop a social innovation ecosystem and promote close collaboration with different stakeholders and especially with civil society. Since public support for this collaboration in the field of social innovation is low, universities must find their own ways to promote collaboration with civil society. Therefore, a systematic community-building approach is necessary.

Technical Universities as Drivers of Social Innovations

According to a report by the World Economic Forum, Germany was one of the world's most innovative countries in 2018. In particular, the report positively highlighted networks between research institutions and companies and the collaboration between various stakeholders [6]. In the field of technical innovation, technical universities are already collaborating with various actors. Technical universities thus already have an existing infrastructure to promote social innovation. In addition, many motivated students are involved in student associations and organizations alongside their studies and are already working on social innovations. Technical universities therefore already have the best conditions to promote social innovation and to act as drivers of social innovation. Social innovation processes, however, require the involvement of different actors and especially of civil society in order to represent the perspective of all members of the society. Nevertheless, many technical universities lack a systematic community-building approach to connect the various actors within the region. This paper presents a community-building approach for technical universities that considers the different actors within a region

2 METHODOLOGY/APPROACH

Within this paper we discuss the community-building approach developed at RWTH Aachen University - a leading technical university in Germany - as an example to illustrate how a regional community can be established between university, civil society and other actors with the aim of promoting social innovation. We show that building a trustful environment and a common narrative are important elements of community-building in higher education.
We first define social innovation and community-building. Taking into account the need and added value for universities by promoting social innovation and the collaboration between academia and diverse actors like civil society, industry or government, we describe our 4-step community-building approach at RWTH Aachen University, a regional embedded technical university in Germany. From this, we derive learnings for other universities, especially technical universities. We conclude by drawing out important implications for developing a supra-regional community-building approach.

2.1 Community-Building and Social Innovation at Universities

A social innovation community should involve actors from multiple areas with different competencies and skills [7]. Based on previous definitions (see [8]), we describe a community as a group of people including e.g. students, scientists, governmental actors and civil society who have a common goal (in our case "social responsibility and building an innovation ecosystem") and who join forces and support each other to achieve a common goal. Mulgan et al. [9] highlight the role of community development in social innovation processes [9]. Social innovations are created through collaborative teamwork, lead to a more inclusive society in the end describe an activity that contributes to solving social or societal problems [4]. The focus is on the satisfaction of a social need and the creation of added value for

society as a whole [9]. Various researchers assume that social innovation can lead to social change. However, this connection has not been widely explored [7].
The development of social innovations often takes place at the interface between different areas. Technical universities offer an existing organizational structure, motivated students and an existing platform that can promote an intensive collaboration between different areas to foster social innovation. In our knowledge society, science can play an important role in the development, testing and dissemination of social innovations. However, the results of a European study show that universities have not yet systematically engaged in the field of social innovation. Research and educational organizations were involved in about 21 percent of the social innovations [10]. Therefore, universities need to create appropriate structures to sensitize people to social problems and possible solutions and to promote the development of social innovations. An important condition is the establishment of a community that covers the broad range of all actors. Social innovations involving various actors and, in particular, society can only succeed if a community is established as a first step.

2.2 Four-Step Community-Building Approach

As one of the largest technical universities in Germany, RWTH Aachen University has recognized the importance of promoting social responsibility and social innovation. For this reason, the Responsible Research and Innovation (RRI) Hub was founded in 2019, funded by the Federal Republic of Germany and its federal states as part of the Excellence Initiative. The aim of the RRI Hub is to become a nucleus for a sustainable and socially responsible orientation of teaching, research and innovation. The RRI Hub is an initiator and platform for joint activities at the interface between science and society. For this purpose, the RRI Hub has successfully established a regional community in a first step. The aim is to connect people with similar goals and to contribute to a sustainable and socially responsible future through collaboration and co-creation. A requirement for building a community between universities and external actors is that this community should be based on reciprocity, interaction and mutual respect. Further elements are the participation of all community members as well as the establishment of a common decision-making process, whereby mutual respect between all actors is important [8].
Based on these community-building principles, a four-step community-building approach has been developed, applied and evaluated, as explained below and shown in Figure 1.

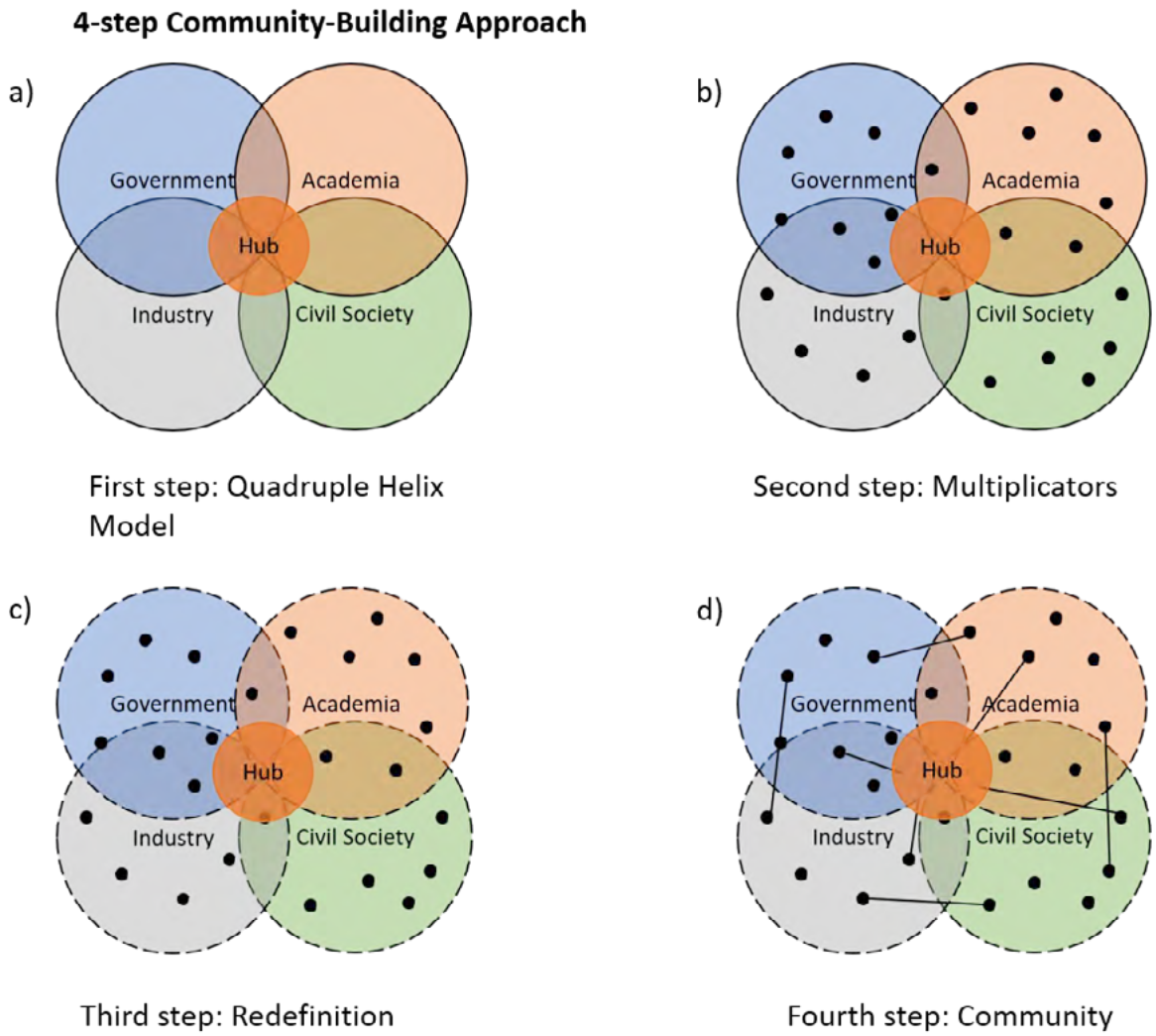

Figure 1: 4-step community-building approach for establishing diverse communities at technical universities

We used the quadruple helix model as the starting point of our community-building approach and identified the following four areas: government, academia, industry and civil society [5]. We used the model to establish a diverse community of actors, as the model made it easier to analyze the regional actor landscape and to quickly identify important actors in each area. Based on our regional approach, the helix government includes all actors employed by the city or involved in local politics. Academic actors are scientists on the one hand and students on the other. With regard to industry, we focused on regional companies in a first step while size and industrial sector were unimportant. Carayannis and Campbell [5] assume that well educated, well informed individuals form the fourth helix (civil society). In contrast to that, we defined the fourth helix involving the entire civil society. Our aim is to build an inclusive community of various actors, in which all individuals who share our interests can be represented. Therefore, only the engagement and interest are relevant, whereas social status, education, or age are no criteria used to build the community. To conclude, the fourth helix in our community-building approach

describes all persons in a society who are interested in collaboration between different actors in the field of social responsibility and innovation. Even though the RRI Hub as a project is located in academia, it initiates, connects and deploys a platform for actors across all areas. Based on our definition of the quadruple helix model, we collected different regional actors in each area. Through research on the internet and existing contacts, we collected all persons who might be interested in a collaboration in a first step. As this step served to collect all possible actors, no further criteria were applied.

We identified multiplicators in all four areas in a second step (see Fig. b)). The reference point for the identification of the multiplicators was the list of different actors, which we already collected in step one. We defined multiplicators as individuals who are well connected within the region and who also have an interest in social responsibility and social innovation. The integration of multiplicators allows us to balance communicational efforts. Multiplicators assigned to the governmental area were mainly persons employed by different departments of the city. These included representatives from the municipal administrations in the fields of business, infrastructure and buildings as well as science. Academic actors were students and chairmen of student associations, members of the general student committee and scientists from different institutes. Particular emphasis was given to addressing interested students. Students do not only have expert knowledge but are also often active members of different associations and non-profit organizations and are already working on social innovation. Industrial multiplicators included employees of regional companies with a focus on sustainability and the social sector. A further focus of our approach was on addressing multiplicators from the civil society. For this purpose, we contacted actors involved in churches, foundations, non-profit organizations or associations. Once the multiplicators had been identified, they were contacted.
In a first step, contact was established by e-mail or telephone. Subsequently, mostly personal meetings with the individual multiplicators took place. These meetings served to get to know each other. Representatives of the RRI Hub as well as the multiplicators presented the goals of their work and current projects. In most cases a first interlinking of the multiplicators also took place. Suitable contacts from the RRI Hub community were shared with the multiplicators, as well as they shared suitable contacts with us. Part of every conversation was the question of the assignment in the quadruple helix. Each multiplicator was asked in which area they would assign themselves. One of the findings from the meetings is that the question of assignment into a single area is not appropriate. One example illustrates the problem: An entrepreneur whom we assigned to the "Industry" area and whom we initially contacted as an industry multiplicator was also the chairman of a non-profit organization and thus assigned to the "Civil Society" area. Overall, we conclude that the assignment into single areas which we call static assignment is not appropriate in the field of social responsibility and social innovation. The engagement of many actors in the social sector is often independent of their actual profession.

Volunteering is the focus here as voluntary work usually takes place in addition to actual jobs in industry, government or science. Initially, civil society multiplicators in particular had reservations about the work and objectives of the RRI Hub in terms of establishing and working with an equal community. Many civil society actors regarded the university as a closed system, which has no interest in opening up to society or collaborating with civil society. Actors regarded universities as a system in which a lot of expert knowledge is available, but often too little attention is paid to social issues. In a third step we therefore tried to reduce these reservations through trust-building activities.

Based on the findings of the second step, we abandoned the concept of static assignment and softened the boundaries of the individual areas of the quadruple-helix model in a third step to allow dynamic and cross-area assignment (see Fig. c)). In this third step, which we are currently working on, we concentrate on the consolidation of the existing network. So far, we have identified two important elements of a successful community-building approach: Trust and a common narrative. To create space for trust-building activities and to reduce the risk of a sense of competitiveness, the RRI Hub chose a two-staged communication approach. In stage one no public relations work of the RRI Hub took place. The focus was on addressing the multiplicators and on the achievements and issues of the civil society actors. The official roll-out of the RRI Hub with the support of the multiplicators is carried out in stage two. In this step, information about the RRI Hub is published on different websites. The multiplicators will be given the opportunity to be presented on this website as well, in order to show mutual respect for the respective work. In addition, the activities will also be communicated via social media channels in the future, so that civil society in particular can access information more easily. The two-staged communication approach builds trust and provides the image of a non-dominant university. Moreover, we argue that trust can also be increased through mutual transparency and respect. For this reason, we regularly inform multiplicators about current activities in telephone calls or personal meetings and inform ourselves about current activities of the multiplicators. These discussions also serve to identify possible topics for collaboration. In consultation with the multiplicators and based on our findings, the common narrative “building a social innovation ecosystem” was developed. The narrative serves to enable all community members to identify with an overarching goal. The common understanding of a narrative involving the multiplicators in a common decision-making process has also contributed to building trust and respect.

The final step of our community-building approach is to establish a sustainable social innovation community with diverse actors. The networking of the various actors is the main focus. In addition to the networking of individual multiplicators, several events and workshops will take place. Besides getting to know each other, the events will provide impulses for collaboration. Individual speakers or multiplicators are invited to present their work, challenges and solutions. Even though all actors are from the

same region, the exchange of information between the individual actors is limited, although they basically pursue the same goals. The aim is to promote collaboration in various cross-area groups with different competences. At the end of step four, a sustainable social innovation community is to be created, which has an established communication structure between the individual areas and in which the RRI Hub acts as an initiator and research member. At the end of this last step of our community-building approach, the community must be known throughout the region and have a positive reputation, so that further multiplicators become aware of the network and want to become part of it. The activities of the previous stages contribute to the popularity and reputation. In the end, the social innovation community will be independent of individuals in order to achieve a sustainable and long-term impact.

3 RESULTS AND LEARNING

This paper describes the development of a community at a technical university. Due to their established innovation infrastructure and numerous motivated students, technical universities have the best conditions to promote social innovation. However, the promotion of social innovation can only be achieved in collaboration with various actors. For this reason, the first step is to build a diverse community. Therefore, the focus was on the development of a diverse community including civil society actors in order to consider the broad range of actors within a region. The described community-building approach has shown that the quadruple helix model must consider the entire civil society in order to cover the broad spectrum of all actors. Through various trust-building activities, it was possible to involve different actors in the community-building process and to establish a regional community. This community includes scientists, university staff, students and student initiatives, entrepreneurs, city employees as well as civil society actors such as chairmen of associations and foundations.

In discussions with multiplicators, the academic ivory tower was a frequently mentioned point of criticism. Actors from civil society and government in particular criticised the fact that universities are not very open to society. Although universities often dominate the cityscape, they are considered a closed system that does not open up to society. Due to the specific terminology citizens feel not being able to understand what the universities are working on. Various actors were initially sceptical as to whether the RRI Hub wanted to establish a truly open and transparent cooperation. Dismantling this scepticism was one of our biggest challenges in establishing the RRI Hub. A successful community-building approach must be able to resolve this. We were able to identify two elements as particularly helpful: trust and a common narrative. Mutual trust has been achieved through the regular exchange of information, mutual transparency and an appropriate two-staged communication approach. Using this approach has showed the partners that the university considers itself a partner at the same level and not as a leading actor. The following sentence served as the common narrative: “Building a social innovation ecosystem". This enabled all multiplicators to identify themselves with a common goal.

Another learning refers to the assignment of multiplicators within the quadruple helix. The static assignment into individual areas in the quadruple helix is not appropriate in the area of social responsibility and social innovation. The engagement of actors in the social field is often independent of their actual profession. We argue that dynamic assignment is more appropriate as it should be possible to assign actors to multiple areas, since many people work on a voluntary basis in organizations in addition to their actual job.

Overall, our results show that the described community-building approach was successful at a regional level. With our approach we have covered the broad range of actors within a community and have also been able to convince those actors who are sceptical towards universities. This can be seen by projects which have already been successfully realized. One example of the successful cooperation with different actors is Aachen's joint application for the "Engagierte Stadt" programme. Together with the city administration, the student committee and a regional foundation, the RRI Hub will test and establish concepts for the promotion of social innovation within the programme. Another first success is the commitment to a joint campaign as part of a sustainability week and the joint establishment of a living lab run in collaboration with city stakeholders.

One limitation of our results is that the community-building approach has so far only been applied at regional level. Due to possible regional differences, the approach may have to be adapted for technical universities in other cities. In a next step, this approach will be transferred to the supra-regional level. One challenge could be that trust-building at a supra-regional level is considerably more difficult due to existing distances and cultural differences that could hinder regular personal communication. An adjustment of the approach is therefore assumed and will be analyzed in more detail in future research. In addition, further studies should examine the extent to which an established regional community can contribute to the development of a regional social innovation ecosystem.

4 ACKNOWLEDGMENTS

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INTERDISCIPLINARY ENGINEERING EDUCATION IN THE CONTEXT OF DIGITALIZATION AND GLOBAL TRANSFORMATION PROCESSES

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Conference Key Areas: *Interdisciplinary engineering education, Sustainability*
Keywords: *theory-based engineering course design for non-engineering students, educational reconstruction, practice-based learning concepts, rapid prototyping, maker culture*

ABSTRACT

Global transformation processes and sustainability issues lead to a rapid increase in problems at the boundary between technical and non-technical disciplines in higher education. Furthermore, new fields of work emerge due to the digital transformation. Graduates need to be prepared to identify and describe problems and to develop appropriate solutions in teams in order to contribute to change processes related to the future in a smart world. Engineering sciences have to take up the challenge to provide suitable educational programs for a broader target group, i.e. non-technical students, especially in light of the current shortage of qualified specialists. This paper contributes twofold to that discourse; (1) by a novel theory-based teaching and learning concept for an engineering course for bachelor students of non-engineering disciplines (e.g. sustainability sciences) and associated empirical findings of implementation, and (2) by innovative project-based laboratory experiments that encourage interdisciplinary approaches. As a specific contribution to the innovative practice of engineering education, part (1) outlines the student-centered lecture scheme "Electrical and Automation Engineering" (four semester hours per week). The framework-based development, the objectives and the didactic design of the bachelor course as well as the engineering key topics in the context of smart technologies and sustainability are presented. Part (2) details novel practices in the area of engineering education by two specially designed lab experiments. Starting from the theory framework, the paper contributes to a theoretical understanding and educational practice of engineering courses designed for a specific group of students at the crossroads of engineering and other disciplines.

1 INTRODUCTION

In today's world, which is characterized by global transformation processes and sustainability issues, engineering sciences continue to be an important shaper of these change processes. In addition to digitalization as a major influencing factor, further changes lead to challenges and modified framework conditions that the engineering sciences have to face [1–5], including:

- changing requirements for the professional field, the subject content and the competence development of students,
- increase in complex global problems, dealing with constant change,
- changes in the institutional framework and in the roles of universities and teaching staff,

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- dealing with diversity, heterogeneous target groups, opening up new target groups to secure young talent and developing interdisciplinary solutions,
- need for new teaching and learning arrangements (including digital, individualized, collaborative).

Furthermore, new fields of work emerge due to the digital transformation. Those novel fields of work can be characterized by high degrees of complexity and responsibility as well as the need for a broad knowledge on topics where disciplines intersect. Graduates need to be prepared to identify and describe problems and to develop appropriate solutions in teams in order to contribute to change processes related to the future in a smart world, cf. [1, 3, 6].

Engineering sciences have to take up these challenges to provide suitable educational programmes for a broader target group (e.g. non-technical students); especially in light of the current shortage of qualified specialists. In this context there is a constant demand for research on theory-based development of targeted didactic concepts for this specific target group and associated empirical findings of implementation.

This paper contributes to that research discourse on transformation processes in engineering education. In section 2, the model of Educational Reconstruction as a theoretical framework for a student-centered conception and implementation of engineering lectures for non-technical students is presented. Based on the framework, section 3 introduces the theory-based lecture scheme "Electrical and Automation Engineering" as a contribution to the translation of educational research to practice. The objectives and didactic design of the bachelor course are shown as well as the curricular implementation. Section 4 presents two innovative project-based laboratory experiments that focus on interdisciplinary teaching in the engineering sciences in the context of digitalization. Finally, the paper outlines the experience of the first implementation of the course in wintersemester 2019/20 and further discusses future perspectives within the discipline of engineering education and research.

2 THEORY-BASED FRAMEWORK AND GOALS

The research objectives in this paper are standing for both theoretical understanding and educational practice. With a focus on the engineering sciences, it deals particularly with the theory-based course-design for students who do not come from a technical field. Furthermore, the presented framework for student-centered course design in engineering is adjusted to constant change (e.g. changes in occupational fields and subject contents, changes in institutional frameworks, increasing complexity and globalization), and to heterogeneous groups of students. The framework is based on Educational Reconstruction, see [10]. The model of Educational Reconstruction is a research framework that is used in scientific education, as in [7, 8]. It is still common in engineering sciences to base the teaching on technical matters. Other aspects like the teaching objective or the perspective of the learners are often considered secondary. To counter this imbalance in the didactic work and to take the students seriously as an active starting point for the construction of knowledge, the model of Educational Reconstruction could be a major help, see [9, 10], especially for that specific target group.

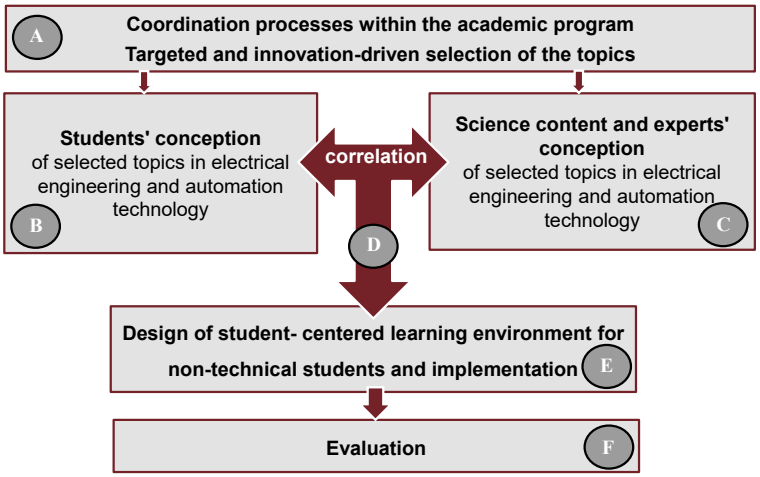

Fig. 1. Model of Educational Reconstruction with focus on engineering and automation technology and non-technical students, based on [7–9]

In the model of Educational Reconstruction, scientific concepts and the perspective of the learners are related to each other. A conclusion about the design of student-centered learning environment is drawn from the comparison. This is particularly important for the didactic construction of engineering courses for non-technical students. In this case, it is a challenge that the majority of students are new to the field and not familiar with it. Therefore, it can be concluded that teaching contents may not simply be dictated in a scientific manner but have to be "created" in a pedagogically useful manner through the conception of the learners themselves, as in [11].

By constructing teaching contents in this way, there are three elements that interact as teaching methodology triplet, [10, p. 4]: the students' perspectives, the clarification of experts' conceptions, and the didactical structuring. As result, a theoretical guided course concept is derived. Fig. 1 shows the generic model adapted for the field of engineering sciences and non-technical learners. To implement the model, the research steps A to F must be completed. The model in all its sequences provides research data that is used for the consistent implementation of study-centered education for non-technical students in engineering education. In the following, these will be described in detail.

At first, the course contents must be coordinated within the curriculum. The goal is *a coordinated and innovation-driven selection of content* that fits the challenges of digitalization and Industry 4.0 (step **A** in Fig. 1). Then, the experiences and the students' conceptions about electrotechnical concepts, particularly in context of Industry 4.0, have to be collected (step **B** in Fig. 1). What view do they have about these concepts and where do they make connections between the theoretical foundations and the practical implementation? The learners' conception is collected by students' self-reports. Besides background on technical subjects, socio-demographic data, and motivation to study a technical minor, the report contains questions for the non-technical students about possible career perspectives. At the same time, the scientific clarification is being prepared (scientific content/experts' conception and correlation, step **C** in Fig. 1). The industrial innovations and scientific key concepts have been identified and analyzed from industry applications and the literature, e.g. [12–17]. What are new industrial developments due to the digital transformation? What do the concepts look like in science? What scientific models exist and where can coherences and limits of the imagination be found? The technical clarification identifies the similarities and the differences of the experts' conceptions and determines which theories they are based on. In step **D**, the learners' understanding about the technical theory is reflected. That way differences between scientific perspectives and the perspectives of the learners are disclosed. Are there existing correspondences to the scientific model? At which point can you build on the learners' conceptions? As a result of this correlation, research-based findings exist that prescribe what has to be regarded while introducing terms, concepts, and models to the special target group of non-technical students. Furthermore, with the goal of fostering students' learning process, the result of the correlation proposes the appropriate course design that is most likely to be successful. The findings of the analysis phase (**A** to **D**) lead to the theory-based development of the design of student-centered learning environment (step **E** in Fig. 1). This design phase of an engineering course for non-technical students is presented in section 3. Further influences are theoretical frameworks like constructivist learning theories, e.g. [18, 19], and gender theories focusing on STEM education, e.g. [20–22]. As a final evaluation (step **F** in Fig. 1), in the first implementation phase we gathered student feedback on the course. The feedback from the students will be incorporated into the process of improvement of the course design. In the next development stages, an evaluation in mixed-method design is planned to get empirical evidence about the effectiveness of the course.

Based on the presented phases of the model, the theory-based development of the teaching and learning concept "Electrical and automation engineering" for non-engineering bachelor students is now illustrated. This bachelor course (4 semester hours per week) is one of six courses of the minor (i.e. secondary subject of the study program) "Engineering Fundamentals", among others Mechanical Engineering, Information and Communication Technologies. The minor "Engineering Fundamentals" provides an overview of the most important technologies and technology-oriented

processes in the manufacturing industry. This minor can be studied in combination with different majors, e.g. Economics, Environmental Sciences and Digital Media.

In times of continuous mechanization and digitalization, a basic understanding of technology is becoming increasingly important in order to actively shape transformation processes at the interface of society, economy, technology and the environment. As described in the introduction, interested non-engineering students have to be empowered to deal with the most important technical disciplines in context of industrial systems, too. The general objective of the new course is to impart a basic understanding of technology in a context relevant for engineering and professional practice. Furthermore, it aims at the following targets:

- imparting knowledge and skills of selected technical basics in electrical engineering, metrology and sensor technologies (including optics) as well as control and drive systems,
- developing close links between basic technical knowledge and possible applications in technical innovations, use of selected examples of systems (e.g. e-mobility, smart sensors, VR/AR), and
- improving the transfer between theory and practice by implementing hands-on sessions ("smart" lab sessions) as well as use of selected digital approaches of teaching.

The strategy for pursuing these objectives is set out in the next section.

3 NOVEL THEORY-BASED TEACHING AND LEARNING CONCEPT

In correspondence to the model of Educational Reconstruction, the development and implementation of the learning environment is presented below. As mentioned before, the student-centered course design originates in constructivist learning theories, e.g. [18, 19] and gender-sensitive teaching concepts, as in [20–22]. The framework-based course design process mainly focuses on two targets. First, the didactic layout of the course should optimally foster learning processes in the highly diverse group of students and make the course attractive to students. Second, the teaching and learning concept actively addresses innovative technologies. Based on a solid fundamental knowledge of engineering, course graduates should be prepared to identify and describe problems and to develop appropriate solutions in teams in order to actively contribute to necessary change processes. These goals and the limited time resources require a focus on paradigmatic innovative technologies and technical content, shown in Table 1. Students get basic knowledge of selected systems, models, and parameters in the range of automation technology (e.g. electrical engineering and electronics, control engineering, and actuator technology) in the context of digitalization and Industry 4.0. They are proficient in methods for calculating simple electrical circuits, acquire practical skills in the analysis of selected automation systems and in measuring relevant process variables. Students acquire professional and methodical expertise that enables them to successfully develop suitable solutions for complex, and at least to some extend technical, problems.

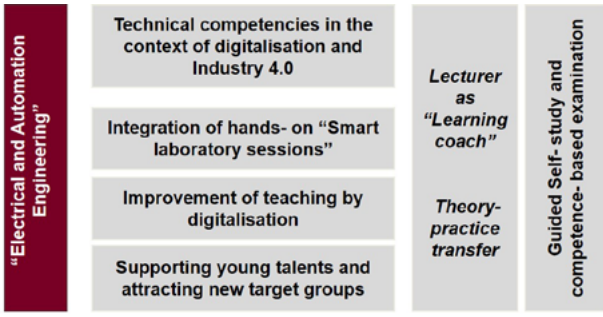

Fig. 2. The theory-based concept of the bachelor course "Electrical and Automation Engineering" for non-engineering students.

The highly diverse group of students requires an innovative teaching and learning concept to integrate different disciplinary cultures and to specifically support those "non-traditional" students in acquiring competences. The course takes up on innovative trends, interaction of technical components in complex and interlinked systems as well as on a strong

Table 1. Topics of the Course "Electrical and Automation Engineering"

Technical contents	Integration of technological innovations and industrial trends in the context of Digitalization
Electrical engineering basics (DC and AC technology)	Renewable energy, solar cell
Measurement and sensors technology	Smart Sensors, VR and AR, Auto Identification (including RFID)
Control and acuator technology	E-Mobility

focus on transfer between theory and practice. For this purpose, the concept integrates ”smart laboratory sessions” as digital approaches to strengthen practical relevance in class. The experiments developed specifically for this purpose are presented in section 4. The process ”know-comprehend-apply”, as well as a strong focus on practice, enables students to transfer individual topics into the context of complex issues analytically and systematically. This is supported by reinforcing interdisciplinary and systematic competences of students, who are encouraged to utilize their individual academic background (e.g. business administration or environmental sciences) to work on problems and case studies. Working on interdisciplinary problems, and getting to know new technical fields independently, prepares students for their future professional life in industry with interdisciplinary and diverse teams. In summary, the concept incorporates the structural elements as seen in Fig. 2. As depicted there and in in Table 1, innovation-based key topics in the context of digitalization, Industry 4.0 and smart laboratory sessions are the centerpiece of the teaching and learning concept. They are expected to allow immediate transfer between theory and practice as well as quick access to understanding complex systems. There are four modular and smart (IT-based, intelligent) laboratories, which are closely related to the concept of Industrie 4.0 [17]. The smart laboratories are useable for both practice sequences during lecture sessions as well as practical experiments and projects of students. In addition, concepts of digitalization are integrated to improve the teaching and learning arrangement. For example, modelling and simulation via Matlab and Simulink software by The MathWorks, Inc. pick up mathematical system models from the smart laboratories and provide an authentic computer simulation and digitally supported failure analysis, while also allowing for graphical software development for embedded systems that interact with the real systems. These approaches are explained in detail in the following section.

4 TWO INNOVATIVE PROJECT-BASED LABORATORY EXPERIMENTS

4.1 AdvancedVisionCar (AVC)

The goal of the experimental framework ”AdvancedVisionCar” (AVC) is to familiarize students with the use of virtual reality (VR), augmented reality (AR) and mixed reality (MR). For this purpose, a platform was created with which not only the handling of the different ”Realities” could be trained, but also the students had the opportunity to test their previous knowledge in the field of sensors.

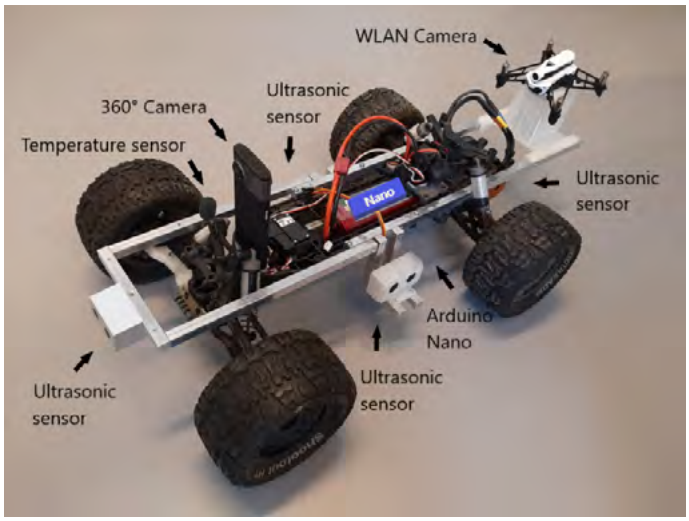

Fig. 3. AVC vehicle with components

This platform was implemented in the form of the AVC, see Fig. 3. The AVC is an RF remote-controlled vehicle with several sensors and camera systems. This vehicle is supposed to bridge the gap between Industry 4.0, the different ”Realities” and a sensible application in the industrial/corporate context. This is achieved by using the prototype vehicle to practice preventive and acute maintenance work in hard-to-reach places. The driver has the option of controlling the AVC via radio-transmitted video outside of their sight. They receive this video stream from the WiFi camera at the rear of the vehicle. It is transferred to a monitor, which also displays the sensor data. In addition, they have the option of recording a 360° video which can then be examined for evaluation purposes after the journey. The sensors on board the vehicle also offer the possibility of detecting temperatures. This significantly improves error analysis. The recorded video can be examined retrospectively with the help of VR glasses and thus give the user the feeling of having been the passenger themself, which improves the

chance of error detection. Microsoft HoloLens is also used to enable the combination with mixed reality. This is used to set waypoints on the course that should be checked regularly. In addition, the HoloLens offers the option of binding error reports to parts of the examination object so that they are available digitally and on site. This means that a user wearing a HoloLens can access these reports as soon as they approach the object under investigation. The complete architecture of the experimental framework can be seen in Fig. 4, more details are given in [23].

The implementation in the teaching context was realized with the help of a trail that the vehicle has to follow. In Mixed Reality, relevant points were also marked out on the route at which measurements were to be carried out. While the driver navigates this course, they must pass obstacles. At the points where there is a marking in the MR, they stop for a measurement. Variables to be measured include temperature and labels that must be recognized by using the video of the 360° camera.

The AVC is equipped with four ultrasonic distance sensors (UDS) and one temperature sensor. The sensors used are four HC-SR04 (ultrasonic sensors) and one TMP36 (temperature sensor). The control and monitoring of the sensors was carried out with the help of an Arduino Nano, which is operated on a 9 volt block and was programmed with the standard Arduino IDE.

Regarding optics, the AVC has a WiFi camera and a 360° camera. The WiFi camera is used for live image transmission to a computer, which the driver uses to orient themself, while the 360° camera records a video of the entire environment. The distance sensors are specially designed to be able to navigate the vehicle in remote-controlled mode without crash. The temperature sensor is located above the vehicle for maintenance and analysis purposes. All sensor data is transmitted live to the computer where it is displayed next to the live image. The VR video is loaded onto an Oculus Quest, which are VR glasses that allow the user to intuitively rotate and look around in the video. The MR data is transferred to a Microsoft HoloLens which another user can wear. Using the data and waypoints in the HoloLens, the other user helps the driver navigate. The waypoints are currently only displayed in the HoloLens. In the future, it is planned to transmit the live image in VR so that the driver can see the entire all-round view while driving. In addition, thanks to the sensors, there is the possibility of linking a neural network to the vehicle control which automatically approaches the marked points and enables measurements. So, the operator could concentrate solely on troubleshooting. Another improvement is the integration of a capacitive sensor for material detection. Furthermore, the sensor data could be transferred directly into virtual reality so that the operator can see live what the sensor is detecting. In addition, this data is to be transferred to the HoloLens in mixed reality, so that a second operator can carry out analyzes in parallel from the outside.

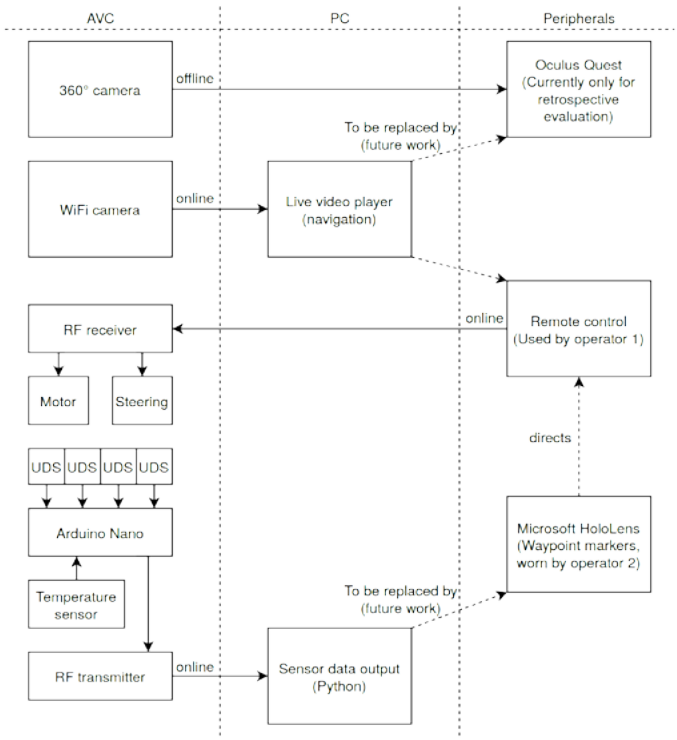

Fig. 4. Schematics, components, and dependencies of the VR/AR experiment

4.2 DC motor

As a second example, a laboratory experiment from the broad field of electrical powertrain technology is presented. (Much more details on this experimentation platform can be found in [24].) The common denominator of this discipline obviously is the electric motor. The simplest possible form (in terms of usage) is the brushed DC motor, since in its most basic function it only requires two leads and an ordinary power supply. In this experiment, a small DC motor is to be controlled using a modern digital embedded platform. An important design goal is the sustainability aspect, achieved by

- using exclusively low-cost hardware that is widely available, compact, lightweight and portable,
- basing the experiment on a standard laptop PC for maximum compatibility,
- using modular components that are as versatilely deployable as possible, and
- using graphical software creation processes, ensuring ease of use to allow for an emphasized focus on key technological aspects instead of e.g. memory management in C.

For graphical embedded software development, MathWorks provides expansion packs for Matlab, so-called Support Packages, for use with the Simulink Coder and Embedded Coder toolboxes. Some (but not all) of these Support Packages, combined with said toolboxes, facilitate four features

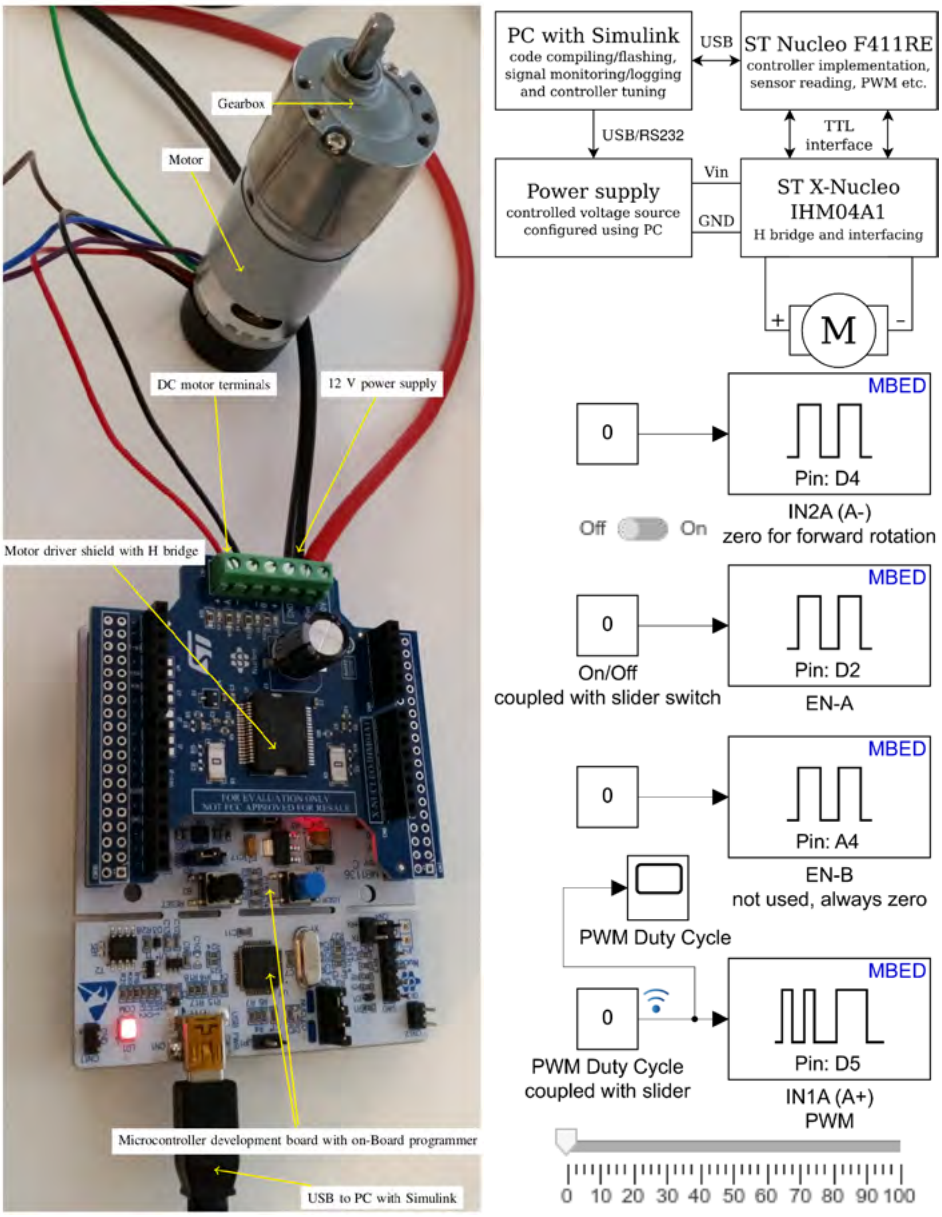

Fig. 5. Left: Experimental setup; Top right: Schematics and interfaces; Bottom right: Manual motor control using interactive elements in Simulink.

that are important for the teaching approach described in this contribution:

1. automatically generate C code from a graphical Simulink model file,
2. cross-platform-compile the code for the hardware target (e.g. ARM architecture) on PC,
3. flash the binary program into the hardware target and run it, and
4. continuously communicate with the hardware target in real time to log signals, tune parameters, switch between program logic paths, etc., i.e. Hardware-in-the-Loop (HIL) and Processor-in-the-Loop (PIL) features.

An aspect of the method that is essential for this experiment is that all four steps are executed consecutively, automatically and within a short time frame, using a single click or command. This is the case e.g. for the STMicroelectronics Nucleo F411RE microcontroller development board [25, 26], which was used in this contribution and is shown within the experimental setup in Fig. 5 (left, the white PCB). There, the other components can be seen, namely the ST X-Nucleo IHM04A1 motor driver shield [27] and an EMG30 motor by Robot Electronics [28]. The described experimental setup can serve as a foundation for many variations of lab experiments related to electrical drives, for example the following:

1. The students are supplied with the material and a laptop PC running Microsoft Windows 10 and MathWorks Matlab and Simulink.
2. They test the online HIL communication between PC and Simulink by flashing the example model shipped with the Support Package (lighting up an on-board LED on press of on-board user button).
3. They assemble power supply and motor, connecting all leads, and ask a supervisor for acceptance before they power on (however, experienced students may complete the experiment unsupervised, since only relatively safe voltage and current levels are used)
4. Students are now asked to implement a manual control scheme to drive the motor, using the supplied documentation, e.g. as in Fig. 5 (right).

5 IMPLEMENTATION AND FIRST EXPERIENCES

The course ”Electrical and Automation Engineering” was implemented for the first time in the winter term 2019/2020. 13 bachelor students (4 female, 9 male) of the major study programmes business administration, economics, environmental sciences and business informatics participated. For the following round of the Minor Program ”Engineering Sciences Fundamentals” 35 students have registered. The aforementioned variety of new fields of work and professional profiles requires high degrees of knowledge and skills from the students with regard to both their minor and their respective majors. Furthermore, the students need the particular skill to systematically form networks of the interdisciplinary knowledge. Imparting the methodological knowledge on working interdisciplinary is an essential part of the course ”Electrical and Automation Engineering”, and of the minor ”Engineering Fundamentals”. This was achieved by the inclusion of different discipline-specific perspectives of students’ majors to develop solutions for scientific questions or case studies. Students and lecturers willingness and motivation to ”bring to life” the interdisciplinary discourse, and their readiness to deal with interdisciplinary problems as well as new scientific fields independently, leads to an profound preparation of students for their future career in interdisciplinary and diverse teams. The lab experiments, which were not compulsory attendence, also proved popular among the students. The small group sessions were highly interactive and agile, due to many interposed questions by students with an advanced technical background, about side aspects and other applications. For others, working with the example systems turned out as a first close contact with technology and a journey with a steep learning curve. Being able to react to such diverse educational preconditions, especially incorporating the skills and perspectives of the non-technical students in a constructive way instead of considering them as the ”weakest link”, requires a high degree of flexibility both from the lab equipment and from the teaching concept. According to the students’ positive feedback on the new course, these goals were achieved. In fact, as justification, they referred in particular to the possibility of combining the engineering fundamentals with their non-technical main subjects.

6 CONCLUSIONS AND ACKNOWLEDGEMENTS

The objective of the paper is to represent an interdisciplinary engineering course concept for bachelor students who do not come from a technical field. A suitable framework for the student-centered course design in engineering education is introduced. The didactic concept actively addresses the diverse backgrounds of the students in this course. This professional diversity carries an important potential to take up an interdisciplinary point of view in class sessions in order to prepare students for globalized scientific and working environments. To facilitate a quick grasp of basic technological aspects, two laboratory experiment systems were developed. They cover AR/VR technology as well as electrical drives, sensors, intuitive programming, control engineering and other related fields. After successful implementation of the combined concept, activities to further establish and extend the concept to other courses (e.g. within the first semesters of the masters degree programme) are planned. Evaluation results will be used to improve the concept continuously and in a systematic manner. Limitations of the conducted study were the small number of students and lack of a quantitative evaluation, since this was the first implementation of the course.

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ENGAGING STUDENTS AND PROFESSIONALS IN ETHICAL REFLECTIONS ON NEW AND EMERGING INFORMATION AND COMMUNICATION TECHNOLOGIES

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Conference Key Areas*: Interdisciplinary engineering education, linking different disciplines both inside and outside engineering, linking with society; Sustainability and ethics, embedded and dedicated approaches.*
Keywords*: Participatory Ethical Technology Assessment; Techno-Anthropology; Automated Decision-Making; Ethics in Engineering Education.*

ABSTRACT

Techno-Anthropology is an interdisciplinary Master's program offered by The Technical Faculty of IT and Design at Aalborg University that addresses human – technology interfaces and, hence, combines disciplinary elements of engineering and the humanities. In this concept paper, we present and analyze a three-day field trip to the annual TechFestival in Copenhagen that included a workshop for students, educators and IT professionals. The workshop was integrated into the Master's program of Techno-Anthropology as a means to teach the students technology ethics by direct interaction with external stakeholders. Hence, the purpose of the workshop was to design, implement and evaluate a participatory, ethical technology assessment teaching format, and consisted of a presentation, practical engagement activities and preparation of individual future road maps. This paper will focus on the context, content and results of the workshop activities. These were centered around a suggested model for collective ethical judgment, which includes the following stages:

1. Identifying ethical issues
2. Linking them to ethical values
3. Identifying ethical dilemmas and placing them in relevant human and non-human networks
4. Engaging participants in value-sensitive discussions aimed at addressing the identified ethical dilemmas provided by the workshop participants.

The paper will outline exemplary participatory design practices that will be of interest to educators and other professionals who work with new and emerging ICTs, and are interested in promoting ethical reflections. The presented analysis identifies the ethical issues, values, dilemmas, networks and solutions suggested by participants, and links them to different aspects of the socio-technical understanding of technology central to Techno-Anthropology. Future research will focus on how to translate the format of the presented experience into other contexts and technology domains that want to enhance their ethical reflection capabilities.

1 INTRODUCTION

1.1 What is Techno-Anthropology?

Techno-Anthropology is an interdisciplinary research area and a Master's program offered by the Technical Faculty of IT and Design at Aalborg University. The research and study program addresses human-technology interfaces. How do humans and technologies interact? This approach is labelled as the socio-technical understanding of technology. It focuses on technical artefacts and human dimensions such as culture and social relations. Techno-Anthropology combines disciplinary elements of both engineering and the humanities. The idea underpinning Techno-Anthropology is often visually illustrated as a triangle with technology users, technology artefacts and technology experts in its three corners (Figure 1).

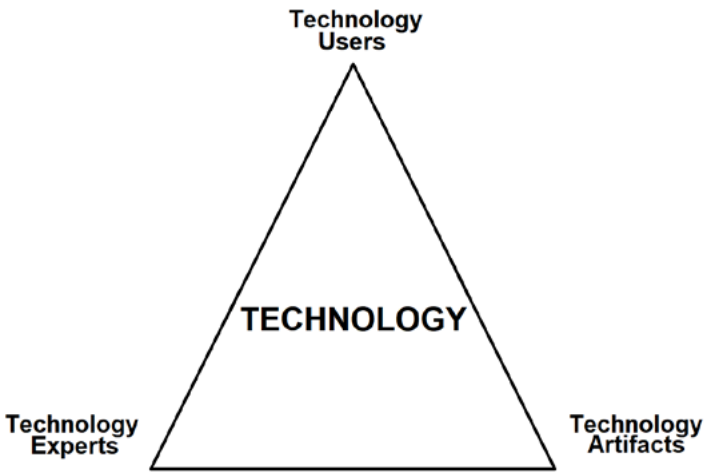

Figure 1. The Techno-Anthropological Field (based on [1]).

The sides of the triangle identify sub-disciplines of Techno-Anthropology: Moving from the artefacts to the users, we see "Technology assessment" emerging [2]. Technology assessment identifies and assesses intentional and unintentional effects of technologies on users. If we go in the opposite direction, from the users towards the artefacts, we find "Anthropology-driven design" which is an endeavour that maps users' needs and translates them into design specifications [3]. We can also move from the users towards the technical experts. In this interface we find "Participatory design" [4] and "Action research" [5]. When we go from the technical experts towards the users, subdisciplines like "Transdisciplinarity" [6] and "Studies of expertise and

experience" emerge [7]. When we go from Technical experts to the Technical artefact we are in the conventional domain of engineering such as "Software engineering". However, at Techno-Anthropology we also embrace "Responsible research and innovation" [8] and "Value-sensitive design" [9] as subdisciplines. Moving from the technical artefact to the technical expert, we see how technical artefacts form and influence research and entrepreneurship. An example of a Techno-Anthropological research project in this area is "How can professionals incorporate AI to make professional estimates". Another Techno-Anthropological research project in this area investigates how university faculty members use digital technologies in their teaching. We have not been able to identify sub-disciplines devoted to the study of how technology influences technology experts.

In this paper we work within one sub-discipline of Techno-Anthropology – between the technology experts and technology artefacts – as we investigate how to promote ethical reflections among technology Master's students, experts and educators in the domains of AI and machine learning. This is a topic relevant to include in engineering education [10]. Engineering ethics teaching objects usually takes the form of lectures, written assignments, case-studies and role plays [11]. Teaching ethics by direct engement with external stakeholders are rarely found and should be promoted [12]. In this paper we present a technology ethics teaching object that centers around an equal meeting between Master's students of Techno-Anthropology and IT professionals.

1.2 Techfestival

In 2019, we offered a techno-anthropological workshop[1] for Master's students and private and public sector IT professionals at the annual Techfestival[2] in Copenhagen. The Techfestival attracts diverse audiences from sectors such as software engineering, public sector organizations, consultancy, etc., which are actively looking for technical and socio-technical solutions to various problems. This context offered us an interdisciplinary group of participants to engage with. The workshop was integrated into the Master's program of Techno-Anthropology as a means to teach technology ethics by direct interaction with external stakeholders. Hence, the purpose of the workshop was to design, implement and evaluate a participatory ethical technology assessment format. The format consists of a presentation, practical engagement activities and individual future road maps for the workshop participants. This paper will focus on the context, methodology and results of the workshop activities.

2 METHODOLOGY & RESEARCH DESIGN

In this short paper, we present and analyze a three-day field trip to the annual Techfestival in Copenhagen that included a workshop for students and IT professionals, interested in the ethical effects of A.I. The paper will outline exemplary

[1] Invitation to the workshop: https://techfestival.co/event/effects-ai-decision-making/
[2] https://techfestival.co

participatory design practices that will be of interest to educators and other professionals who work with new and emerging ICTs, and are interested in promoting ethical reflections.

2.1 Quick and Proper Participatory Ethical Technology Assessment

In this paper we present the Quick and Proper Participatory Ethical Technology Assessment (PETA) model/format[3] that is developed by the authors. PETA promotes collective ethical judgement of an existing or emerging technology, and is suitable for use in ethics teaching of Master's students and professionals working with new and emerging technologies. The idea is to set up an extended peer-community, e.g. by organising a workshop where different stakeholders are invited. The idea is to collect differentiated experiences with the effects of the assessed technology. The model includes the following steps:

2.1.1 Identifying Ethical Issues

The first step in PETA is to identify possible effects of the technology under assessment. This is done by asking the assessed technology's extended peer-community[4] to brainstorm and discuss i) the intended good consequences of the technology under assessment, ii) how it can be misused, iii) what unintended consequences the technology can have, and iv) how it might affect human culture and societies in the long run.

2.1.2 Linking Ethical Issues to Ethical Values

An ethical value is understood as a normative criterion against which one can compare the wider consequences and circumstances of the use of a given technology. During the 2018 Techfestival an interdisciplinary group of festival participants produced the Copenhagen Catalogue[5], which is a list of 150 ethical "*principles for a new direction in technology*". The catalogue can guide the development and application of hardware and software. The values were formulated through participatory co-design.

Hence, the second step of PETA is to liaise the ethical issues identified during step one to relevant ethical values. We provided the participants with a card deck including all 150 values, divided the participants in groups and asked them to identify the values they found most relevant for A.I. and machine learning in their own and their fellow group member's professional fields.

[3] The model side of PETA is focused on defining concepts (technical, socio-technical, ethical, methodological, etc.). The format side of PETA deals with how these concepts are applied in a real-world setting.
[4] Extended peer-communities covers both members of a technology's traditional peer-community (e.g. software engineers, UX designers, etc.), and members of non-obvious peer-communities, who are facing ethical issues posed by the assessed technology. Our workshop facilitates brainstorming in discussion for communities that may not traditionally interact with each other.
[5] https://www.copenhagencatalog.org/

2.1.3 Identifying Ethical Dilemmas

PETA's third step operates with a distinction between an unethical situation and an ethical dilemma. We have an unethical situation if the technology under assessment violates ethical standards without being justified by any other ethical value. An ethical dilemma refers to a situation where ethical values are in collision.

The purpose of the third step of the PETA model is to decide whether a technology generates an unethical situation and hence is ethically wrong and should not be developed or used, is not associated with ethical problems and can be applied without ethical concerns, or creates an ethical dilemma, where the situation is ambivalent. Latter cases call for ethical judgment, decision-making and value-sensitive design.

At Techno-Anthropology the first, second and third steps have been applied to a number of cases: risk reducing surgery [13], an ethical pig stable [14], the use of DDT [15], psychotropics and other enhancing technologies [16], and automated decision-making [17]. These texts can be read in preparation to attending in a PETA workshop.

2.1.4 Engaging Participants in Value-Sensitive Discussions

Value-sensitive design is an ethical approach to overcome ethical dilemmas by design. The idea is to maintain already inscribed ethical values while changing the design so that new ethical values, those who are violated in the assessed socio-technical configuration, are inscribed by changing the design.

The socio-technical configuration needs to be changed in order to address the ethical dilemma by involving interdisciplinary competencies. This means to 1) identify actors and actants that can influence and drive a change in the technology under assessment, and 2) arrange a shared theoretical and practical ground for actionable discussions to occur. This includes identifying interests of human actors and intentionality of nonhuman actants, which should be recognizable and actionable by either or both sides [18].

Addressing ethical dilemmas using value-sensitive design is not a value-neutral act; as such the fourth PETA step demands high levels of reflexivity and awareness regarding participation (who/what is an actor/actant), issue visibility (what can each side perceive as an ethical issue), and commitment (specific steps that relevant human and non-human networks can be positioned around to address the identified ethical dilemmas).

The learning objectives associated with the PETA teaching approach is both to generate knowledge of a technology's ethical issues, link them with ethical criteria and to make ethical judgments in a transdisciplinary context of different and complex perspectives.

2.2 The Workshop

In September 2019, the authors organized an interactive workshop titled “The Effects of A.I. and Automated Decision-Making” (ADM) at Copenhagen’s Techfestival. We used the term ADM instead of Artificial Intelligence or Machine Learning to include automated, reflexive, unconscious decision-making processes in humans as well as in machines, where A.I. and M.L. apply. The workshop enacted the PETA model by engaging an audience of students and technical experts from different industries. There were four main goals that the workshop addressed: 1) creating a common ground for concepts and definitions; 2) creating an engaging technological narrative to serve as a boundary object facilitating a shared understanding of ADM and the ethical assessment methodology; 3) creating a participatory environment; 4) setting up an ethics teaching object based on interaction between students and external stakeholders.

The workshop was attended by ~90-100 participants, which were arranged in small groups of ~6-7 people. The groups produced 3 deliverables as they went through 3 rounds of exercises. The deliverables include 2 lists (intentional and unintentional effects of ADM and ethical values relevant to the participant’s own line of work) and 1 personal, actionable roadmap to solve the identified issues.

After establishing shared concepts and definitions, **the first round** aimed to identify, reflect and share thoughts about selecting relevant ethical values / principles from the 2018 Techfestival’s Copenhagen Catalogue, and how they are relevant for each group member. The **second round** focused on the ambivalence of ADM, where participants became a “human algorithm” and were instructed to sort the 150 values / principles in the Copenhagen Catalogue by very specific criteria (size, shape, etc.). Ambivalence arose when discussing why each group had a different answer to the exact same set of criteria. The **third round** inspired participants to be professionally and socially engaged via ethical discussions and ethical dilemmas in the design of ADM. They were to translate their group reflections to actionable plans for their specific technical, professional or business area. All participants gathered in plenary with concrete examples from their professional experiences. They were identifying new values that could support the detection of ethical tensions in their own field with the help of fellow participants. Two volunteers debated their individual approaches in front of the entire audience.

Figure 2. Personal roadmap to support individual ethical reflections on automated decision-making

As a final task, participants used a roadmap instrument (see Figure 2, above) to facilitate prospective thinking in the future, and as a tool to share the workshop experience with their colleagues at work.

Techfestival 2019 marks the identification of ethical values (among those 150 included in the Copenhagen Catalogue) during the workshop as a starting point (red point). Participants were encouraged to repeat the exercise identifying ethical values relevant to additional specific cases and dilemmas in at least two additional milestones (yellow & blue points). A follow-up meeting was proposed for Techfestival 2020 where participants can share the experience and results of implementing the workshop's exercises.

3 RESULTS

3.1 Ethical Assessment

The presented ethical analysis identifies only the ethical issues suggested by the workshop participants. How the ethical issues liaise with ethical values, networks and solutions was not agreed upon. The results of the shared ethical assessment from the workshop are four ethical issues regarding automated decision-making, and are summarized here as follows:

3.1.1 Black Boxed Information Selection

A central point in the ADM domain is that decisions made by computers are rarely based on shared (socio-)technical principles, and similar technologies can have wildly different results. Practically, this makes it impossible for humans to know *how* decisions are made in an ADM context, thus resulting in a classical black-boxed situation.

3.1.2 Wicked Algorithms

If the input is flawed, so is the output. This goes under the heading "junk in, junk out". It is also possible to manipulate the data input to prevent an A.I. system from serving a beneficial purpose. A traditional understanding of algorithms as impartial tools is complicated into *wicked* algorithms that are malleable in unforeseen ways.

3.1.3 Unequal Distribution of the Fruits of Digitalization

A digital transformation will affect different target groups in different ways. Digitalization can both benefit workers by improving their job conditions, but also result in loss of jobs all together. Stakeholders with knowledge and power advantages are unlikely or unable to share the benefits of digitalization where they are most needed.

3.1.4 Political Consequences of the Internet of Things

The more information is generated by internet-connected IoT devices, the more politicians can promote decision-making to an "input-output formulae" as is seen in China, where some public behaviour is regulated through registering citizens' digital traces and making them a subject for peer assessment. Such wide-ranging effects of internet-connected devices, many of which operate under ADM processes, have deep political consequences, which require attention.

3.2 Processual Lessons from the Workshop

We present four main lessons for organizers of workshops with focus on ethical assessment of ADM processes.

3.2.1 Consider Participants Individually and Engage Personal Experience

Relevant stakeholders and interested parties may instinctively be approached as different types of groups: different professions, disciplines, sectors, minorities, and so on. It is critical to engage individual perspectives from different points of view, which hold ADM expertise in a broad sense (including user perspectives). For example, a workshop participant who uses machine learning models to evaluate university student retention and participation[6] was engaged by another participant who provided consulting services to African governments as part of his position in the Danish Foreign Ministry. These different perspectives, engaged individually, were able to better explain and reflect upon their role in the functioning of their respective institutions, as well as to receive relevant professional feedback they would not have looked for otherwise.

[6] This participant wrote a blog post on her experiences at the workshop: https://www.version2.dk/blog/forudsigelse-eller-prognose-1089370

3.2.2 Create Shared Experiences and Understandings of what Algorithms are Doing

One way to visualize nuanced ethical issues with regards to automated decision-making is to transform workshop participants into metaphorical logic gates that enact criteria set by a supposedly objective and clear algorithms. When asked to perform "objective" criteria on a set of cards, our workshop participants immediately identified the flawed aspect of an "objective" algorithm, regardless of their professional or educational background. This simple exercise (see Figure 3 below) illustrates how each individual can highlight ethically problematic aspects of ADM quickly by comparing their professional experience to other expertise.

Figure 3. Workshop participants order Techfestival Principles by a simple and "objective" criteria (e.g. font size, etc.) in the *Becoming the algorithm* exercise

3.2.3 Recognition of Ethical Issues in Personal Work Cases

It was possible for the workshop participants to reach agreement on the identified ethical issues. No consensus on which ethical values were linked to which ethical issues was reached, however. Neither did the group reach unanimity with regard to solutions and networks. We do not know if consensus can be achieved in these areas. We need more research to draw such conclusions.

3.2.4 Learning by Opening Up

One can explain participation as a balanced interaction between power and learning. One of the assumptions for participation is that those who gain power relying on technical expertise are required to open up for learning. Users' contributions were sharing knowledge with technical experts, and at the same time they gained power. We as techno-anthropologists assumed the role of facilitators in the interplay of power exchange. The Copenhagen Catalogue was useful to focus on ethical discussions and made participants relate to them. Interdisciplinary participation became visible when participants exposed a myriad of interpretations of the same values / principles.

Figure 4. Example of the Techfestival Principles

4 CONCLUSION

As techno-anthropologists we use methodologically and theoretically flexible ways to address and analyse the entangled relationships between humans and technologies. What separates techno-anthropological approaches from other approaches is a formal structure to interdisciplinary mediation. Blurring boundaries between disciplines diminish the impact of participation and co-creation. Techno-Anthropology acts as translator and facilitator among subjects; thus, uncertainty and confusion in the borders can decrease. In this regard, and as stated in the techno-anthropological triangle (Figure 1), the workshop was a relevant avenue to assess ADM as a technical artifact. The workshop systematically illustrated the tension between users and technical experts with regards to ethical issues and values related to technologies.

It is noteworthy that the exercise allowed attendees to alternate between roles. The participants were acting as technology experts when identifying what elements are relevant for strengthening their understanding of ADM technologies while listening to users (Learning). They were anticipating and developing, as technology users, concrete actions, and new values required to build confidence and minimise undesirable effects of the technology, thus raising empowerment (Power). Beyond the ethical reflections, another consequence of the workshop demonstrated the different aspects such as networks, values, ethical issues, and possible solutions to understanding the socio-technical configuration of technology central to Techno-Anthropology. Finally, having presented the PETA model and the road map to help attendees to implement the workshop in their fields, it was our contribution to pinpoint the weight of responsible research and innovation as a subdiscipline that requires more attention in novel technologies like ADM.

The attending students and other participants learned both about AMD technologies, their ethical issues (black boxed information selection, wicked alghoritms, unequal distribution of risks and benefits of digitalisation and political issues of the internet of things), as well as of the advantages of involving different stakeholders in ethical technology assessment, exchanging power and learning within an extended peer-community, creating shared understanding and translating all this into personal action. Hence, the presented PETA ethics teaching object is relevant to include in engineering

ethics education because it aligns well with what Jeroen van den Hoven calls for when he states that:

> Multidisciplinary and interdisciplinary collaboration is very important. This is a much needed development in academia. The solution to the big and urgent problems in the world will not be found in one discipline, in one journal or in one book. Moreover, adequate solutions will always be systems' solutions, and they will most likely deal with technology and human behavior with values and norms. [19]

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DEVELOPING AN APPLICATION TO GATHER AND CENTRALIZE THE INFORMATION OBTAINED FROM THE INNOVATION COMPETENCIES ASSESSMENT IN MASSIVE PROJECT-BASED COURSES

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ABSTRACT

Today innovation is essential in any country that aims to increase its economic growth and the welfare of its population. Therefore, organizations need to innovate and provide meaningful solutions to their customers to succeed in an ever-changing business ecosystem. It implies that their collaborators must be capable to manage and implement innovation. Consequently, engineering schools are facing the challenge to provide capable engineers in this matter to the job market to satisfy organizations and society needs. Motivated by the need to develop in engineering students the capability to lead and perform innovation successfully, it is critical to understand how to perform the teaching process in a way to ensure proficiency in innovation at the end of the study programs. A project was started to understand which methodologies support the development of competencies associated with the probability to produce innovations. Based on the literature and the innovation track curriculum, three competencies were chosen to be assessed; critical thinking, teamwork, and communication. After implementing the first course of the innovation track several difficulties were found. The teachings staff set a group of actions to close the detected gaps. In order to implement them, it was recognized the need to develop an application to gather and centralize the information obtained from the assessment process.

The main characteristics of this application are described, and its benefits are discussed. This application will enable engineering schools to establish a data-based decision-making process to implement a continuous improvement philosophy in the organization.

1. INTRODUCTION

Today innovation is essential in any country that aims to increase its economic growth and the welfare of its population (OECD, 2012). As an example, the European Commission, in order to invigorate the European economy, has put the innovation policy as a central element (Fagerber and Verspagen, 2009). At the same time companies are concerned about their ability to innovate, and they are aware of its importance for their future (Christensen, 1997; Christensen and Raynor 2003).

Considering this fact and the need of organizations to innovate and provide meaningful solutions to their customers to succeed in an ever-changing business ecosystem, it is necessary that their collaborators be capable to manage and implement innovation. Therefore, engineering schools are facing the challenge to provide capable engineers in this matter to the job market to satisfy organizations and society needs. Considering the need to develop in engineering students the capability to lead and perform innovation successfully, it is very important to implement the assessment cycle in a way that ensures the development of the competencies related to innovation at the end of the study program. In this article, the case of an application to gather and centralize information, resulting from the innovation competencies assessment, will be treated. The application purpose is closing the gaps detected during the implementation of the new engineering and sciences track curriculum in the year 2019. This year, the first of three project-based courses, with a specific focus on developing competencies that correlate positively with the possibility to implement innovation, was implemented. The first course must be taken by 900 freshmen students in 9 sections of 100 students each.

The first part of the document introduces the theoretical background that supports the competencies selected to be assessed in these courses. Secondly, the competencies assessment process is explained. Thirdly, the first course of the track is explained as well as its improvement opportunities related to assessment. Finally, the design and implementation plan to improve the course assessment process, based on the application, is discussed.

2. THE INNOVATION COMPETENCES

One of the concepts that today is capturing the attention of companies around the globe is innovation. As a matter of fact, innovation is becoming a central part of the efforts of companies to stay ahead in their business and ensure their subsistence in the future (Christensen, 1997; Christensen and Raynor, 2003). At the same time countries are increasingly caring about this topic because they have understood that it is one way to ensure economic growth and social development (Faberger and Verspagen, 2009; OECD, 2011). A clear example is the fact that the European Commission has recognized that higher education institutions are not contributing as much as they should to innovation in the wider economy. In addition, the performance varies between EU regions (Laura-Maija, Lindfors, Taatila, 2017). Also, scholars are increasing their interest on the topic, data show a considerable number of publications since the early ’90s (Faberger and Verspagen, 2009). In addition, more than 100 centers or departments are doing research on innovation, most of them located in Europe (Faberger and Verspagen, 2009). This evidence supports the idea of developing the innovation competence in engineering students, mainly because they will work in an industry where innovation is a core feature for organizations to survive and grow in an ever-changing market, and these organizations will contribute to counties’ growth.

Before continuing our discussion, it is relevant to explain the definition of innovation. Early definitions date from the late 1880s, however the most influential precursor of this concept was the economist Joseph Schumpeter (Sledzik, 2013). Schumpeter defined innovation as “process of industrial mutation, that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one”. Many definitions of innovation have been created in the last decades, however, a broadly accepted definition by scholars is the one proposed by Amabile, who defines innovation as the successful implementation of creative ideas within an organization (Amabile, 2016). In this definition, creativity is considered as part of the process of innovation, as a matter of fact, creativity is defined as the production of novel and useful ideas by an individual or a group of individuals working together (Amabile, 2016). In this line Miron, Erez, and Naveh (2004) state that the implementation of creative ideas leads to innovation. In addition, it is relevant to notice that both are grounded in the assumption that creativity and innovation are subjective constructs, socially bound by historical time and place, and perceptions of usefulness likely vary even within a given domain at a given time (Amabile, 1982,1983).

According to the Dynamic Componential Model of Creativity and Innovation (Amabile, 2016), one of the most recognized models to explain innovation in organizations, innovation is explained at the organizational level, and in its process requires the generation of ideas that emerge from the individual or small group creativity. In this creative process, three elements are fundamental to the process to occur, these are; intrinsic and synergistic extrinsic motivation, skills in the task domain, and creativity-relevant processes. In the modern definitions of innovation, we find two concepts that are included almost in every definition of innovation, novelty, and usefulness. In this model, Amabile (2016) states that organizational innovation is fed by individual/group creativity to produce ideas. At individual or small group level creativity is influenced by the intrinsic motivation, the skills in the task domain and creativity-relevant processes.

After understanding the basics of the innovation concept, it is important to understand how the competence concept has been defined. In the literature, competence represents a set of skills especially as it is applied to a task or a set of tasks (Dej, 2007). In a more complete definition, the concept competence (plural competencies) identifies both the combination of related traits, knowledge, values, attitudes, skills, and abilities embedded in determined context and process of development of them as an integrative construct (Edwards-Schachter et al., 2015). In the same line, the individual innovation competence is understood as a synonym for a set of personal characteristics, knowledge, skills, (or abilities) and attitudes that are connected to creating concretized and implemented novelties via collaboration in complex innovation processes (Laura-Maija, Lindfors, Taatila, 2017). From the previous definitions, it is possible to infer that innovation competence involves several complex elements that present a relevant challenge from the teaching and assessment perspective.

Continuing in the line to enlighten the comprehension of the innovation competence, the literature suggests that innovation competence is a composition of multiple factors and or sub-competencies that could predict innovation to occur if they are present at the individual and/or organizational level.

Regarding the state of the art of innovation competence, it is required to analyze how it can be assessed. According to Butter and Van Beest (2017) Universities do not have tools to measure the development of students' innovation competencies during their studies. Therefore, we do not actually know what teaching and learning methods are effective from the perspective of enhancing innovation competencies. Universities and companies need new reliable and valid tools for innovation competence assessment that could be used throughout the young innovators' path from university to working life in organizations. This statement coincides with the literature review performed for this document, showing the need to perform research in this area based on quantitative methods and develop reliable tools for the assessment process.

Butter and Van Beest (2017) carried out a study to validate the Fincoda model proposed by Marin-Garcia et al. (2016), which proposed creativity, critical thinking, and a cluster of capacities composed by initiative, teamwork, and networking as predictors of innovation.

Creativity: The ability to think beyond existing ideas, rules, patterns or relationships. To generate or adapt meaningful alternatives, ideas, products, methods or services regardless of possible practicality and future added value.

Critical thinking: The ability to analyze and evaluate the advantages and disadvantages and estimate the risks involved for a purpose.

Initiative: The ability to influence/make decisions that foster positive changes. To influence creative people and those who have to implement the ideas.

Teamwork: The ability to work effectively with others in a group.

Networking: The ability to involve external/outside stakeholders outside the team.

In the results of the research was found that relevant innovation process competencies can be measured in an adequate manner. Also, the criterion (creativity, critical thinking, initiative, teamwork, and networking) validity seems satisfactory. The FINCODA dimensions are positively and significantly related to all three types of criterion measured. These are 1) self-ratings of innovative behavior, 2) supervisor ratings of innovative behavior, and 3) real-life examples of innovative

behavior. Also, FINCODA shows incremental validity above general personality. The analyses consistently show that showing initiative is the most determinant of being a successful participant in the innovation process and innovation teams, in the sense that this competency adds predictive power above background variables and personality in predicting innovation behavior (Butter and Van Beest, 2017). However, there are some limitations and needs for further research. An important distinction, that is remarked by Butter and Van Beest (2017), is the need to make differentiated analyses for different educational programs and countries. As an example, it is proposed to study the difference between technical and social work domain students.

In the context of the design of the innovation track and based on the curricular design and the results indicated above, three competencies were chosen to be developed in three innovation courses of the new curriculum. These were critical thinking, teamwork, and communication.

3. COMPETENCIES ASSESSMENT

The competence-based model was implemented in the engineering faculty in 2019. This decision was taken because this model, as Villa and Poblete state (2008), *provides greater enrichment of learning methodologies, closer monitoring, and tutoring of students individually and in a group as well as a range of techniques for assessing learning*. In this model implementation, exists a focus on formative assessment following the recommendation indicated by UD (2006) *The course assessment system must include not only aspects related to final exams before issuing final grades but also includes everything concerned with the formative assessment*.

Assessment by competence means first knowing what we want to evaluate, second explicitly defining how it is going to be evaluated, and third specifying the level of achievement for the course. The teaching staff implemented this approach when designed the assessment system in the first course in the innovation track.

In the implementation, the teaching staff applies strategies such as observation techniques, self-evaluation, and attitude scales for teamwork assessment. On the other hand, the teaching staff applies strategies such as writing essays, the application of knowledge to specific situations, and the development of different types of thinking (analysis, synthesis, comparison, critical, creative, comparative, deliberative, etc.) to assess communication and critical thinking respectively. Finally, the teaching staff inserted all these assessment strategies in the innovation process experienced by the students in the course project.

3.1 Critical thinking

Critical thinking plays a relevant role in innovation, Marin-Garcia et al. (2016) define critical thinking as the ability to analyze issues, evaluate advantages and disadvantages, and estimate the risks involved for a purpose.

Villa and Poblete (2008) state that to develop critical thinking it is required to create situations where assumptions can be examined and checked against others. The object of the analysis will always be our own and others' discourse and actions either directly expressed or observed or else gleaned from written documents or audiovisual content. According to Bhutta et al (2019), a large number of methods ranging from standard tests to more performance-oriented, authentic open-ended techniques such as interviews and portfolios, have been developed and validated to assess critical thinking. In the context of this article, the approach indicated by Bhutta et al. (2019) in which the development of the 'Assessment of Critical Thinking' (ACT) rubric consist of four interlinked phases: (i) identifying main elements of CT; (ii) deciding on the CT rubric format; (iii) adapting CT assessment rubric; as well as, (iv) field-testing and establishing reliability was implemented by the teaching staff. They, after revising the learning outcomes of the course, and based on what Pascarella and Terenzini (1991) state; "critical thinking can be defined in several ways, but typically involves the individual's ability to do some or all of the following: identify central issues and assumptions in an argument, recognize important relationships, make correct inferences from data, deduce conclusions from the information or data provided, interpret whether conclusions are warranted based on the data given, and evaluate evidence or authority", created a list of indicators associated with critical thinking in the context of the course project. Finally, a rubric was developed and implemented in the course evaluation milestones. The rubric is in Appendix A.

3.2 Teamwork

Innovation literature and industry requirements remark the importance of teamwork as a key competence to succeed during the innovation process at the organizational and small team level (Amabile, 2016). In the context of innovation competences, Marin Garcia et al. (2016) define teamwork as the ability to work effectively with others in a group. In a complementary and more detailed perspective, De Los Rios et al. (2012) define teamwork competence as a set of actions, strategies, procedures, and methodologies used by a group of people to achieve objectives and/or goals, sharing responsibilities. Teamwork involves group creation where people meet, collaborate, and interact specifically for a particular purpose (work or project), covering three main lines of action: team building, teamwork, and group dynamics.

Regarding evaluation, the methodology implemented in the course implies an initial activity in which the teams elaborate a contract in which each member of the team sets his/her expectations concerning the other members' performance in aspects such as; obligations and agreements commitment, respect to others, organization, and tasks accomplishment. Then, the students perform a 360-behavior assessment

between teammates through a questionnaire where they evaluate each other in the aspects agreed in the contract. After that, they make an individual evaluation, using a self-assessment survey, and write an individual reflection on their performance. It occurs two times in the semester, in week 9 and week 15. The teaching staff designed the rubrics for teamwork competence assessment, they are shown in Appendix A.

3.3 Communication

The professional and academic communication competence is defined as: Analytically read and listen to different types of relevant texts for the student learning process. Likewise, express in an effective, clear, and informed way his/her ideas, in academic situations, both in oral as in written modality in the Spanish language (FCFM, 2018). Therefore, two dimensions must be assessed in the course by the teaching staff; oral communication and written communication.

Written communication involves the ability to effectively convey multiple types of messages, in multiple forms, to varying audiences, through a written medium (Markle et al., 2013). On the other hand, oral communication is defined as expressing clearly and opportunely one's ideas, knowledge, and feelings in speech, adapting to the audience and, situations to ensure good comprehension and attention (Villa and Poblete, 2008).

The evidence to assess oral communication is collected by the teaching staff from the project presentations in weeks 8 and 15. On the other hand, the written communication evidence is gathered by the teaching staff in the reports delivered by students in weeks 8 and 15. To create an assessment tool for oral and written communication, the teaching staff review the levels and descriptors proposed by Villa and Poblete (2008) and adjusted them according to the curricular design learning goals. The results of this process are shown in the rubric in Appendix A.

4. COURSE DESCRIPTION

The new engineering curriculum, implemented in the year 2019, integrates the development of innovation competence as a fundamental learning goal. Three courses were designated to develop this competence in the innovation track, these are; innovation challenge (1st semester), innovation project (2nd semester), and interdisciplinary module (4th semester). The stem of these courses is an innovation project, framed into the United Nations Sustainable Development Goals (SDGs). The final deliverable is a prototype of the solution.

The three courses have the aim to develop three sub-competencies associated with innovation; critical thinking, teamwork, and communication. These competencies are developed progressively in three levels of authenticity and difficulty. Concerning assessment, each course has two evaluation milestones (summative), the first in

week 8, and the final in week 15. Also, the course has formative assessment instances. Each of these has an individual component and a group component.

In this article, the focus is on the case of the first course called innovation challenge. The formative and summative assessment instances for this course are listed and briefly described in Appendix B.

The indicators associated with the course innovation challenge, for critical thinking, teamwork, and communication are described in detail in Appendix D.

The teaching staff based on the indicators in Appendix D, developed the rubrics for the course for teamwork, communication and critical thinking (part of innovation). The results are show in Appendix A.

Each course receives 900 students per semester distributed in 9 sections of 100 students each. In these sections, the students are divided into 20 groups of 5 members to work on the course project. The teaching staff consists of two engineering teachers, two design teachers, and two final years students.

5. COURSE IMPLEMENTATION DIFFICULTIES AND IMPROVEMENT OPPORTUNITIES

After teaching the first course in 2019, several obstacles and improvement opportunities were identified. To gather the opinions of the teaching staff, a survey to detect the most impactful difficulties was carried out. The results showed that the most relevant obstacles during the implementation of the two courses were; a high number of hours spent on processing the information coming from each assessment milestone, post assessment feedback is delivered late to the students, the assessment information stays contained in separate files that make it difficult to perform further analyses, the information granularity does not allow the team to perform detailed analyses to improve the course performance.

These difficulties impact directly on the competencies development for some students. Considering this, the teaching staff defined four strategic goals to focus its work; improving the time to process the data from the assessment process, registering all the assessment activities per student in the three courses, ensuring the accessibility, quality, and granularity of the data acquired during the assessment process, and performing analyses that contribute to implement a data-based decision-making process in the innovation track to ensure achievement of the competencies defined in the curriculum.

After defining the strategic goals, the teaching staff determined a series of specific actions to close the identified gaps. The specific activities and their objectives are listed in table 1.

Table 1. Strategic goals and associated actions

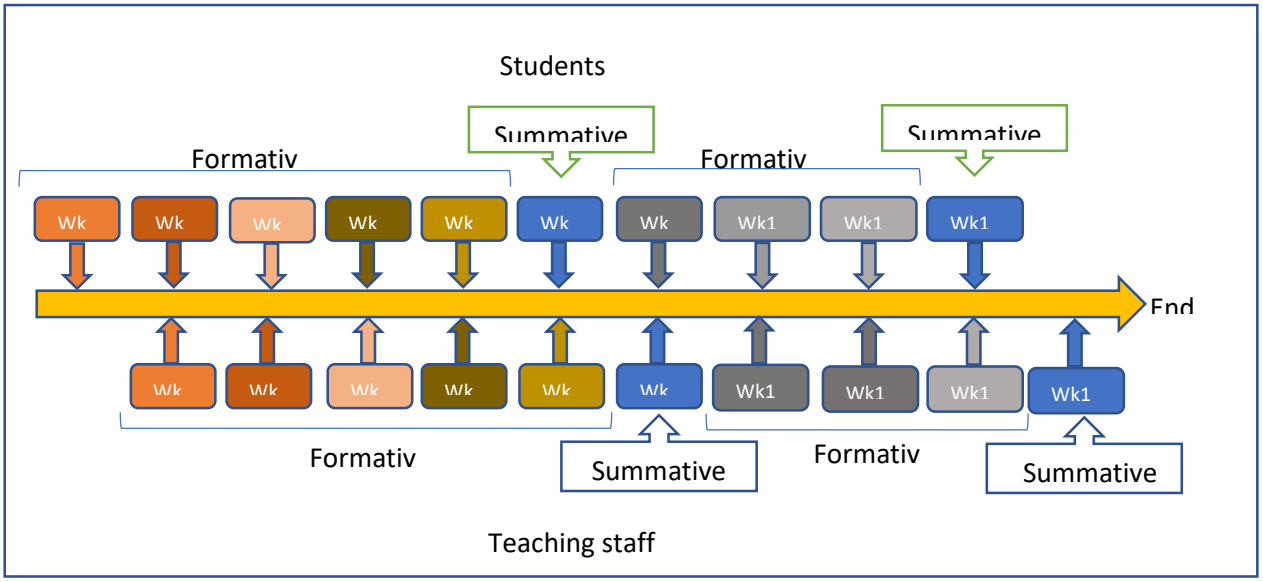
Strategic goal	Objective	Action
Improve the time to process the data from the assessment process.	Reduce the time to provide prompt feedback to students.	Implement an easy access web database management system.
Register all the assessment activities per student in the three courses.	Centralize and facilitate access to assessment information.	Create a web-based platform to manage centrally all the information gathered from the assessment process.
Ensure the accessibility, quality, and granularity of the data acquired during the assessment process in one database.	Increase the capability to perform analyses to establish a data-based decision-making philosophy in the innovation track.	Create a web-based application to store and manage the data from the assessment process.
Perform analyses that contribute to implement a data-based decision-making process in the innovation track to ensure achievement of the competencies defined in the curriculum.	Ensure the development of the three competencies to be developed in the course; critical thinking, communication, and teamwork.	Implement analysis tools in the web-based applications to perform analysis.

As a result of the activities indicated in table 1 the decision of creating a web-based application to manage all the information coming from the assessment milestones of the three courses was taken. In the next section, the description of the features defined during the design phase will be explained.

5.1- Web-based assessment tool design feature

The basic actions to comply with the course, formative and summative, are detailed in Appendix C. A graphical description of them is shown in figure 1. In this figure, it is noticeable the number of interactions that are needed to gather the evidence in the assessment process. Also, it is remarkable the complexity for the teaching staff to manage the evidence when it must deal with many students.

Figure 1



In Appendix E the cycle for the two types of interactions in the process are described in detail.

Several features and their objectives were defined to be included in the first application prototype during the design phase. These are: implementing the competency assessment rubrics in the web-based application to facilitate the assessment process, implementing a database that connects information that characterizes student (gender, age, city, etc.) with the rubrics to centralize and facilitate access to assessment information, including in the application a dashboard that allows teaching staff to see the achievement level per indicator and its associated learning outcome including filters such as student gender, age, course section, teachers, date of the evaluation, etc. to increase the capability to perform analyses to establish a data-based decision-making philosophy, and creating a virtual portfolio for each student, where he/she can review his/her achievements and the projects in that he/she participated to increase student awareness on his/her performance to promote his/her reflection on his/her learning process.

In the next phase, a team conformed by the course's teachers, educational experts, and application developers will be put in place to initiate the detailed design and implementation phase. A process to capture best practices and lessons learned will be implemented. These outcomes are expected to be communicated in a future article describing the challenges associated with the detailed design, implementation and testing phase.

6. FUTURE RESEARCH

Once the implementation of the web-based innovation competencies assessment tool is finished, several research topics can be developed. The teaching staff determined to define four topics to be researched in order to focalize the resources involved in this project. The first topic is the validation of the impact of the tool in the development of the competencies associated with innovation. The second research topic is understanding the reduction of the time dedicated to performing the assessment process. The third topic is assessing the quality of the data obtained using this tool, and finally, a full-scale implementation will be performed to determine the impact of these three variables in three courses. In this process is recognized the need to work interdisciplinarity including professionals from with educational research background, software and application developers, and engineering and design professionals with an innovation background.

7. CONCLUSIONS

During the creation of a strategy to assess innovation competencies development, in massive project-based courses, the need to implement a web-based application has been recognized by the teaching staff. This application requires the integration of several features that were detected during the courses' implementation by the team. The reasons that justify this effort are related to operational aspects of the course and research opportunities originated in the massive quantity of information gathered during course execution. The most relevant operational aspects to improve are: reducing the number of hours spent on processing the information coming from each assessment, reducing the time to provide feedback to students, integrating the information obtained from the assessment process in a system able to manage it easily, and increase the information detail to allow the teaching staff to perform further analyses. Regarding research opportunities, the most relevant are; validating the impact of some class activities in the development of the competences, comparing the development of the competences between groups of students such as gender, previous background, etc., and validating the contribution of the innovation track model to the development teamwork, communication, and critical thinking. In the design phase, the teaching staff defined attributes that the application has to offer to its users. The actions to include this features are the following: providing the capacity to create or upload the rubrics in the application, implementing a database able to centralize and store the information from the assessment process in each course of the innovation track, creating an online portfolio where he/she can review his/her achievements and the projects in that he/she participated, creating a dashboard to present graphically the results of students' learning process regarding competence development. In this project, it has been detected the relevance of implementing data management tools to guarantee an easy and effective administration of the information resulting from the assessment

process. There are still challenges related to the effective implementation of the application in the course. Most of this challenge is related to the willingness of the teaching staff to adopt this technology in their duties, this implies providing the resources to properly understand the students and teaching staff needs regarding interface design and user experience. Finally, the benefit of this implementation will allow faculty to understand the real impact of the activities in the courses' program to achieve the levels established for each of the competences defined in the curriculum and install a data-based decision-making philosophy to manage the innovation track.

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Appendix A: Course Rubrics

FINAL REPORT RUBRIC					
Written and oral communication descriptors					
Indicators	**Excellent** **3 points**	**Very Good** **2 points**	**Good** **1 point**	**Poor** **0 points**	**Total points**
Conveying important information (*)	Noteworthy for the clarity in speech of reasoning and/or feelings.	Express well-reasoned ideas.	Present some ideas.	Expresses self poorly or confusedly.	
Controlling nerves sufficiently to express self in public (*)	Expresses self with ease and noteworthy proficiency.	Expresses self with a certain tranquility.	Speaks but it noticeably nervous and ill at easy.	Can't speak due to nerves; gets blocked.	
Field questions (*)	Responds well and easily to the questions that she/he is asked.	Knows how to respond to the questions that she/he is asked.	Responds to the questions that she/he is asked without actually answering them.	Doesn't know how to respond to the questions that she/he is asked.	
Visual aid: Formal aspects of infographic structure title, body, source, credits	The infographic is presented in the format and with all the requested aspects correctly elaborated and are consistent.	The infographic is presented in the format and with the majority (70%) of the requested aspects correctly prepared.	The infographic is presented in the format and with half of the requested aspects correctly prepared.	The infographic neglects the formal aspects, more than half of the requested aspects are absent.	
Visual aid: Text and visual resources relationship	All visual resources (images, tables, graphics) comply with the formal aspects of this type of resource and facilitate understanding.	Most of the visual resources (images, tables, graphics) comply with the formal aspects and allow understanding.	Not all visual resources are formally adequate, making it difficult to understand the message.	Visual resources are not formally adequate and impede understanding of the message.	
	The infographic texts are organized in a balanced way, use correct sentences and images (tables, charts), and suit the context of the final presentation.	The infographic does not present all the relevant information regarding the topic covered in the final presentation.	The infographic presents an overload of textual information and scarce visual resources. Or an excess of visual information and little textual information. The infographic becomes monotonous.	There is information overload and absence of visual resources. Or there is no textual information and excessive visual information. The infographic becomes monotonous.	

Appendix A: Course Rubrics

Written and oral communication descriptors					
Indicators	**Excellent** **3 points**	**Very Good** **2 points**	**Good** **1 point**	**Poor** **0 points**	**Total points**
Report writing: Formal writing and bibliographic sources	Correctly apply the citation rules (APA). The writing and spelling of the text are adequate, allowing an understanding of the writing.	Correctly apply the citation rules (APA). It presents small inaccuracies in the writing or spelling, but this does not prevent the understanding of the writing.	Applies with some inaccuracies the citation rules (APA). Writing and spelling errors appear, which make the writing difficult to understand.	The citation rules (APA) are not applied correctly, or it does not present it. Errors and mistakes in spelling and writing are abundant, impeding the understanding of the writing.	
Clearly expressing ideas, knowledge, or feelings (*)	Organizes the report sections and paragraphs.	Presents the different aspects of the topic in logical order.	Expression can be understood but the report is disorganized.	Uses confused, hazy, expressions. Very difficult to follow.	
Writing well grammatically (*)	Utilizes prepositions and conjunctions well.	The report is correct as far as spelling and syntax are concerned.	Make spelling mistakes.	Omits subjects or verbs. Uses wrong mood, tense or persons in verbs.	
Using appropriate language for the type of document and reader (*)	Uses synonymous to clarify ambiguous or equivocal terms.	Suits language to the type of document and reader.	Uses the terminology of the subject incorrectly.	Uses own abbreviations or jargon.	
Using appropriate devices to facilitate reading and comprehension of the report (*)	Clearly identifies the essay and its key elements.	Appropriately uses typographic devices (font, paragraph, style formats, etc.)	Overuses formatting devices, hindering comprehension.	Doesn't use typographic devices (font, paragraph, style formats, etc.). Doesn't number pages.	

(*) Indicators and descriptors taken from Villa and Poblete (2008).

Appendix A: Course Rubrics

Innovation (Critical thinking)					
Indicators	**Excellent** **3 points**	**Very Good** **2 points**	**Good** **1 point**	**Poor** **0 points**	**Total points**
Describing findings and observations	The student describes the most important findings or observations related to the problem to be solved.	The student describes the findings and observations, which are related to the problem to be solved, but are not the most important.	The student describes observations that are not directly related to the problem to be solved.	The student does not present findings, or the observations have no relation to the problem.	
Describing the user	The student describes properly the user and his/her most distinctive characteristics.	The student describes the user and only one of his/her distinctive characteristics.	The student poorly describes the user or does not describe his/her distinctive characteristics.	The student does not describe the user or does not describe his/her distinctive characteristics.	
Describing the problem	The definition of the problem to be solved is consistent with the user and the main findings.	The definition of the problem to be solved is consistent with the user or the main findings.	The definition of the problem is weakly related to the user needs or the main findings.	The definition of the problem is not related to the user needs or the main findings.	
Listing the objectives of the project	The objectives of the project are related to solving the problem.	At least one objective of the project is presented, and it is related to solving the problem.	The objectives of the project are weakly related to solving the problem.	No objectives are presented.	
Presenting the proposed solution at conceptual level	The student shows the proposed solution, using the syntax indicated in the course: What is it? (name that defines it) + For whom? (user) + How? (concept of solution and general operation)	The student shows the proposed solution, using the syntax indicated in the course, although there are inaccuracies.	The student shows the proposed solution, but it does not comply with the syntax indicated in the course.	The student does not show the proposed solution.	

Appendix A: Course Rubrics

Innovation (Critical thinking)					
Indicators	**Excellent** **3 points**	**Very Good** **2 points**	**Good** **1 point**	**Poor** **0 points**	**Total points**
Presenting a pertinent solution to the user's problem	The student describes the proposed solution, and this is consistent with the user, with the defined problem and its objectives. The details of the innovation and the attributes that characterize it must be described.	The student describes the proposed solution, and this is consistent with the user, or with the defined problem or its objectives. The details of the innovation and the attributes that characterize it are partially described.	The student describes the proposed solution, and this is weakly consistent with the user, or with the defined problem or its objectives. The details of the innovation and the attributes that characterize it are partially described.	The student describes the proposed solution, and this is not consistent with the user, nor with the defined problem nor its objectives. The details of the innovation and the attributes that characterize it are not described.	
Critical analysis of the Project	The student reflects on the project carried out, highlighting the beneficiaries of the solution and those affected. The student reflects on the potential resolution of the problem and its future feasibility.	The student partially reflects on the project carried out, highlighting the beneficiaries of the solution and those affected. The student partially reflects on the potential resolution of the problem and its future feasibility.	The student reflects only on one of the aspects requested by the teaching staff.	The student does not reflect on the aspects requested by the teaching staff.	

Teamwork-Self assessment					
Indicators	**Excellent** **3 points**	**Very Good** **2 points**	**Good** **1 point**	**Poor** **0 points**	**Total points**
I performed the tasks assigned to me / by the group within the required deadlines	I fulfilled the assigned tasks in the required terms, my contribution was remarkable to the team, and my work facilitated other members work.	I fulfilled the assigned tasks in the required terms, my contribution was not remarkable to the team, and my work partially facilitated other members work.	I partially fulfilled the assigned tasks and didn't fulfilled the scheduled activities.	I didn't fulfilled the assigned tasks.	

Appendix A: Course Rubrics

I participated actively in the team meeting spaces, sharing information, knowledge and experiences.	I was active and participative in the group meetings. With my interventions I encouraged participation and improved the quality of the team's results. My contributions were fundamental both for the group process and for the quality of the result.	I was active and participative in the group meetings. With my interventions I neither encouraged participation nor improved the quality of the team's results.	I was seldom active and participative in the group meetings. With my interventions I neither encouraged participation nor improved the quality of the team's results.	I was not active and participative in the group meetings. I was neither active nor participative in the group meetings.	
I took (took) into account the points of view of others and I provide feedback constructively.	I accepted the opinions of others and I gave my point of view in a constructive way. I encouraged constructive dialogue and inspired participation from other group members. I integrated the opinions of others maintaining a climate of collaboration and support.	I often accepted the opinions of others and I gave my point of view in a constructive way. I often encouraged constructive dialogue and inspired participation from other group members.	I seldom accepted the opinions of others and I gave my point of view in a constructive way. I seldom encouraged constructive dialogue and inspired participation from other group members.	I never accepted the opinions of others and I gave my point of view in a constructive way. I never encouraged constructive dialogue and inspired participation from other group members.	

Appendix C: Course activities and assessment milestones

Week	Class objective	Student deliverable	Group or individual activity	Type of assessment	Assessed competence	Grade %
1	Course presentation	-	-	-	-	-
2	Introduction to SDGs	-	-	-	-	-
3	Community observation, Part 1	Report, observation findings.	Individual	Formative	Critical thinking	-
4	Observation findings, interpretation	Report, findings interpretation.	Teamwork	Formative	Critical thinking	-
5	Community observation, Part 2	Report, observations finding.	Teamwork	Formative	Critical thinking	-
6	Problem definition based on observations	Problem statement and its evidence.	Teamwork	Formative	Critical thinking	-
7	Understanding the user and reframing the problem	Report, reframing the problem.	Teamwork	Formative	Critical thinking	-
8	Intermediate presentation	Oral presentation and report including process evidence and problem statement.	Individual and Teamwork	Summative	Oral and written communication, critical thinking	40% of final grade
9	Feedback session	Peer and self - assessment.	Individual and teamwork	Formative	Teamwork	-
10	Conceptualization and idea generation	-	-	-		-
11	Conceptualization and idea generation	Drawings, sketches.	Teamwork	Formative	Critical thinking	-
12	Idea selection and validation	-	-	-		-
13	Idea selection and validation	Selection matrix, surveys to potential users, low-resolution prototype.	Teamwork	Formative	Critical thinking	-
14	Final presentation preparation		Individual and Teamwork	-		-

Appendix C: Course activities and assessment milestones

Week	Class objective	Student deliverable	Group or individual activity	Type of assessment	Assessed competence	Grade %
15	Final presentation	Oral presentation, and report including process evidence, problem statement, generated ideas, selection matrix, surveys to potential users, analysis, low-resolution prototype, and peer and self -assessment.		Summative	Oral and written communication, critical thinking, teamwork	60% of final grade

Appendix C: Assessment activities per week

Act.	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6
Student actions	None	None	Action 1.1: Student uploads observation findings report. Word file.	Action 2.1: Student uploads observation findings interpretation report. Word file.	Action 3.1: Student uploads observation findings interpretation report. Word File.	Action 4.1: Student uploads problem statement and its evidence. Word file.
Teaching staff actions	None	None	None	Action 1.2: Teaching staff uploads observation findings report feedback. Word file.	Action 2.2: Teaching staff uploads observation findings interpretation report feedback. Word file.	Action 3.2: Teaching staff uploads observation findings interpretation report feedback. Word file.
Act.	**Wk 7**	**Wk 8**	**Wk 9**	**Wk 10**	**Wk 11**	**Wk12**
Student actions	Action 5.1: Student uploads report, reframing the problem. Word file.	Action 6.1: Student uploads oral presentation video and intermediate report. Video file and word file.	Action 7.1: The student provides feedback to his/her peers, self assesses his/her performance and indicates his/her commitments for the rest of the semester in the app.	None	Action 8.1: The student uploads team sketches and drawings produced during the conceptualization and idea generation stage. Pdf file.	None

Appendix C: Assessment activities per week

Act.	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11	Wk12
Teaching staff actions	Action 4.2: Teaching staff uploads file. Word file.	Action 5.2: Teaching staff uploads report, reframing the problem feedback. Word file.	Action 6.2: Teaching staff grades the deliverable in the app.	Action 7.2: Teaching staff reviews student feedback to his/her peers and his/her commitments in the app.	None	Action 8.2: The teaching staff provides feedback on sketches and drawings produced during the conceptualization and idea generation stage in the app.

Act.	Wk13	Wk 14	Wk 15	End
Student actions	Action 9.1: The student uploads the selection matrix, surveys to potential users, and low-resolution prototype pictures. Pdf file.	None	Action 10.1: The student must upload a video of his/her team oral presentation, and a report including process evidence, problem statement, generated ideas, selection matrix, surveys to potential users, analysis, low-resolution prototype, and peer and self - assessment. Video and pdf file.	None

Appendix C: Assessment activities per week

Act.	Wk13	Wk 14	Wk 15	End
Action Teaching staff actions	None	Action 9.2: The teaching staff provides feedback on selection matrix, surveys to potential users, and low-resolution prototype pictures in the app.	None	Action10.2: Teaching staff grades the deliverable in the app.

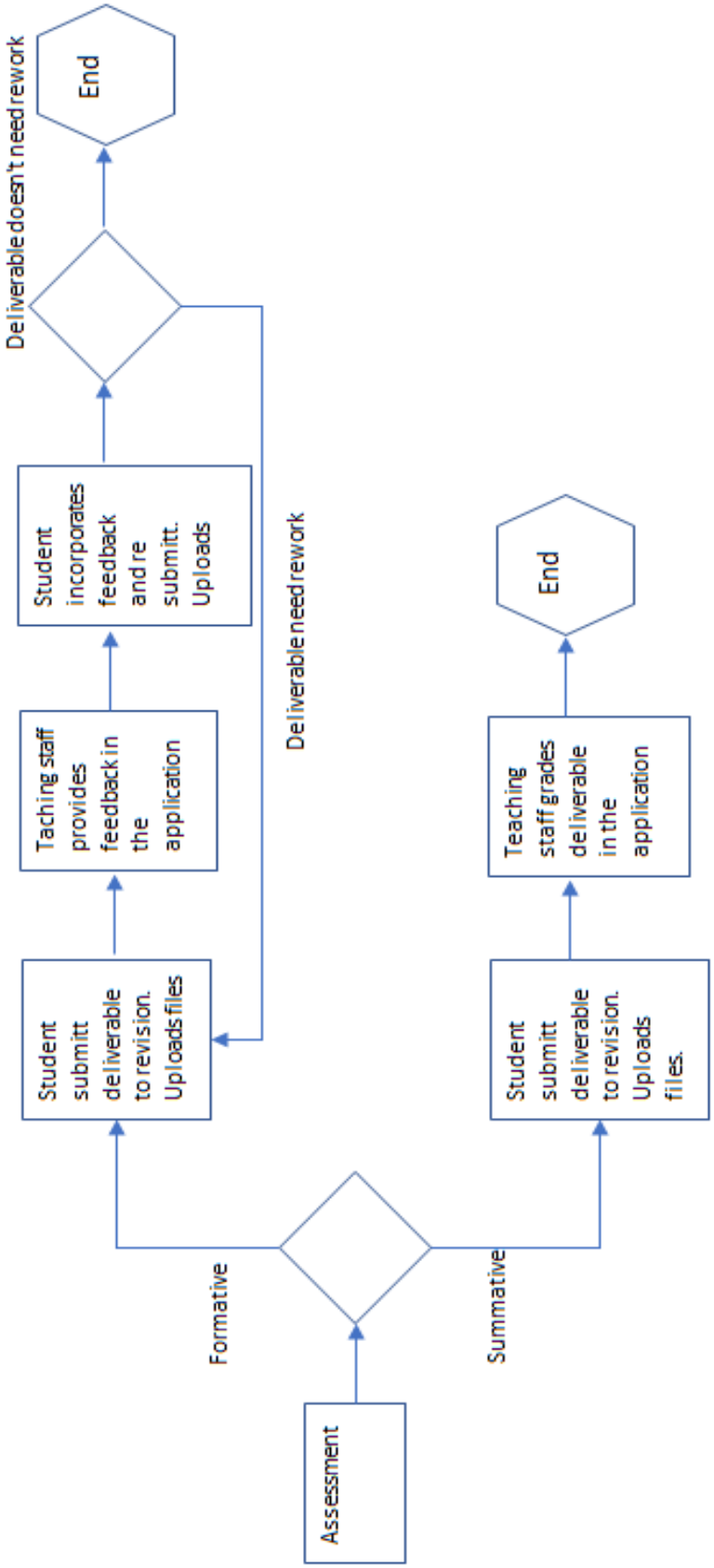
Appendix D: Indicators per competence

Competence	Indicators
Oral Communication	The student orally expresses his/her opinions and learning in formal contexts, cautioning the use of time, diction and, eye contact with the audience.
Written Communication	The student writes reports that manage to integrate information collected from various authors and the experience of the observation phase, generating documents of their authorship.
Written Communication	The student describes the problem to be solved, using correctly the syntax defined for the course.
Written Communication	The student communicates the innovation process results, explaining the final solution features, the difficulties faced during the process, and how the team solved them implementing the tools taught in the course.
Teamwork	The student fulfills obligations and agreements, respecting the commitments acquired, in his/her academic activities and with the team.
Teamwork	The student expresses his/her opinions to the team clearly.
Teamwork	The student reviews his/her performance critically and provides constructive feedback to his/her peers.
Teamwork	The student organizes tasks, deadlines, and roles with which he/she commits.
Critical thinking	The student compares his/her previous beliefs, regarding an innovation challenge, with the visions of his/her peers and the collected evidence.
Competence	Indicators
Critical thinking	The student utilizes the necessary instruments to implement the field phase, applying data capture and recording techniques.
Critical thinking	The student inquiries about antecedents associated with an innovation challenge or need, using the suggested bibliography.
Critical thinking	The student interprets the information gathered from an ethnographic approach, managing to understand a need or challenge.
Critical thinking	The student describes the problem to be solved correctly, using the syntax defined for the course and reframe it according to the recommendations made by the teaching staff and the team's analysis.
Critical thinking	The student defines hierarchical attributes of a solution at a conceptual level linked to usability and user experience on product performance.

Appendix D: Indicators per competence

Critical thinking	The student communicates a conceptual solution to the innovation challenge, using a correct syntaxis, the user needs, and the reframed attributes in hierarchical order.
Critical thinking	The student utilizes diverse techniques to systematize his/her solutions to the innovation challenge.
Critical thinking	The student detects mistakes and achievements during the design process, analyzing the causes to extrapolate possible future improvements.

Appendix E: Summative and formative assessment process to be implemented in the application.



HOW CAN TECHNOLOGY ENHANCED LEARNING IMPROVE THE EFFICIENCY AND QUALITY OF HELP SEEKING AND GIVING FOR PROGRAMMING TUTORIALS?

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ABSTRACT

Programming tutorials are self-regulated learning activities where students are responsible for their own work pace and learning experience. They are working on programming assignments under supervision of teaching assistants (TAs), where help seeking is an essential skill. Especially, the ability to formulate specific questions contributes to higher test results. In addition, the likelihood of seeking help can be increased by electronic measures, as it is perceived as less threatening.

During programming tutorials at the University of Twente the queue management system *TA-help.me* is used. In order to improve the quality of the learning process, this system was expanded by the following features:

1. Students had to choose a **category** to which their question belongs.
2. Students had to **formulate their question** or select a previously asked question.

The extentions resulted from a Creative Technology Design process. For evaluation, quantitative data were gathered to measure the quality of the help seeking of students and the acceptance of the tool. Furthermore, TAs were interviewed to check if the tool improved the efficiency and quality of the help seeking and giving.

The data indicate that the amount of improvident help seeking reduced, the categories were perceived as useful by the students. Furthermore, adding categories to the questions offered the TAs the opportunity to select topics and to spread their attention more effectively. Typing out the questions did, however, not increase the amount of more specific questions asked.

Future research includes how to guide students to ask better questions.

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1 INTRODUCTION

1.1 Programming Tutorials

Programming tutorials are self-regulated learning activities where students are responsible for their own work pace and learning experience. They are actively working on programming assignments or projects under supervision of a teacher or teaching assistants (TAs) [1]. The effect of a tutorial as learning activity is the ability of students to practice and experiment with the subject matter under supervision. This learning activity allows the students to ask for help from meaningful resources, such as peers and teaching staff, when they are stuck or they want to learn something. In programming tutorials, TAs are a critical resource for which students have to compete, TAs regularly loose overview whom to help first, and give the same explanations multiple times. Students, on the other hand, often ask TAs to debug their non-working code instead of approaching them with a clearly defined question. In this situation our starting point is the research question:

> *How to design a system that makes scaffolding programming tutorials more effective?*

To answer this question, we followed a Creative Technology Design process [2]. It begins with an analysis of the context, and an identification of the problems in detail. These provide the starting point for a design phase, and later evaluation.

For help seeking in programming tutorials problems in format and in quality were identified. The hand-raising problem is a pure format problem: students seeking for help raise their hand until a TA is available. While waiting with a raised hand, it is difficult to continue to work, making waiting a waste of time. Solution for this is a queuing system for help seeking and giving. For the quality of help seeking it was found that most questions of students were unspecific. Accordingly, we addressed an improvement of the system that supports the formulation of specific questions.

1.2 Help seeking and help giving

During tutorials, students have to be able to evaluate if they are able to complete the exercises and when they need to seek help to meet their goals. The need for help cannot be seen as a direct function of the reported help seeking of students [3]. It is often seen that individuals avoid seeking help [4] or do not seek help effectively [5] . Learners can avoid help seeking because of prejudices as seeing seeking help as weakness or because of disliking public attention [3].
Webb et al. [6] defined three levels of help seeking: specific questions, general questions, and making errors. They discovered that asking help with specific questions related positively to achieving the goal and was statistically related to higher test results [6]-[9].
Van de Meij found that children with relatively poor vocabularies asked significantly more unnecessary questions than children with good vocabularies [10]. This may also apply to students new to programming. Sharing questions and strategies may help other students to learn how to formulate their question and understand their

problem better. In [11] it was found that students prefer to ask for help via electronics means. Several studies concluded that seeking help by electronic measures provides privacy and is perceived as less threatening by students [3], [12], [13]. When traditional educational activities make use of technology to support their learning activity it is called technology enhanced learning (TEL).

Help giving is the process of responding to a request from a help seeker or someone in need. Downs formulates ten tips for the supporting staff of learning [14]. Besides practicing and feedback, the staff must make sure that students ask for help. The likelihood of seeking help can be increased by reducing the perceived costs that are induced when learners are concerned to perform worse than others in the class [3]. Help giving can be divided in high level help and low level help. Low level help can be seen as unhelpful helping. The help giver gives the help seeker the desired answer, without explaining the steps to get to that solution [6]. High level help is achieved when the help giver explains what steps have to be taken to solve the problem, then watches while the help seeker tries to solve the problem, helps with errors that may occur, asks follow-up questions to make sure the help seeker has understood the explanation, and lastly gives the help seeker praise [6]. In order for high level help to be effective, the help seeker needs to be mentally prepared for the high level help. Students who ask general questions or give a statement of confusion are not ready to receive high level help, because they first need to figure out what their level of knowledge is and where they need help. Whereas students asking help with specific questions receive high level help and benefit from it. When asking a specific question the student's brain creates space to store the solution to that impasse. Furthermore, specific questions generate targeted explanations [6].

2 METHODOLOGY

The methodology followed a process of Creative Technology Design [2]. It starts with an analysis of the context, resulting in a better understanding of the stakeholders, the situation, and background from literature. Characteristic for the subsequent design phase is an iterative process, in which (partial) solutions are generated, evaluated, and improved. The iterations end with the product or solution designed. The last phase consists of an evaluation, where the solution is evaluated in its context, together with the users and stakeholders. In the following we will describe the approach chosen in our design process.

2.1 Context Analysis

The analysis of the context includes interviews with the stakeholders, observation of tutorials and literature.

2.1.2 Interviews of the stakeholders

The stakeholders identified in the context of programming tutorials are teachers, teaching assistants, students, and supporting staff. All the stakeholders were interviewed. With eight teachers of programming courses and the tutorials, semi-structured interviews were conducted, giving the experts the ability to elaborate on

their experiences and to add personal insights to the interview. Questions were on their background, practice of tutorials, pitfalls, and experience with TEL tools. To get the opinion of the students and teaching assistants, five TAs and two students were interviewed in two focus groups. Group interviews provide a wider bank of data than individual interviews, respondents comment on each other and initiate responses, respondents stimulate each other to discuss, and respondents become more genuine because they are not required to answer every question [15]. Furthermore, a staff member of the supporting team was interviewed about his perspective and requirements for newly developed TEL applications.

The interviews conducted during the context analysis were synthesized into personas. Personals are fictional characters based on data from interviews. They can help to understand the type of person at whom the design is aimed, being a widely used technique in Human Computer Interaction and other design areas[2]. Six personas were developed in total. For illustration we include here one example for a persona for a teaching assistant in Figure 1.

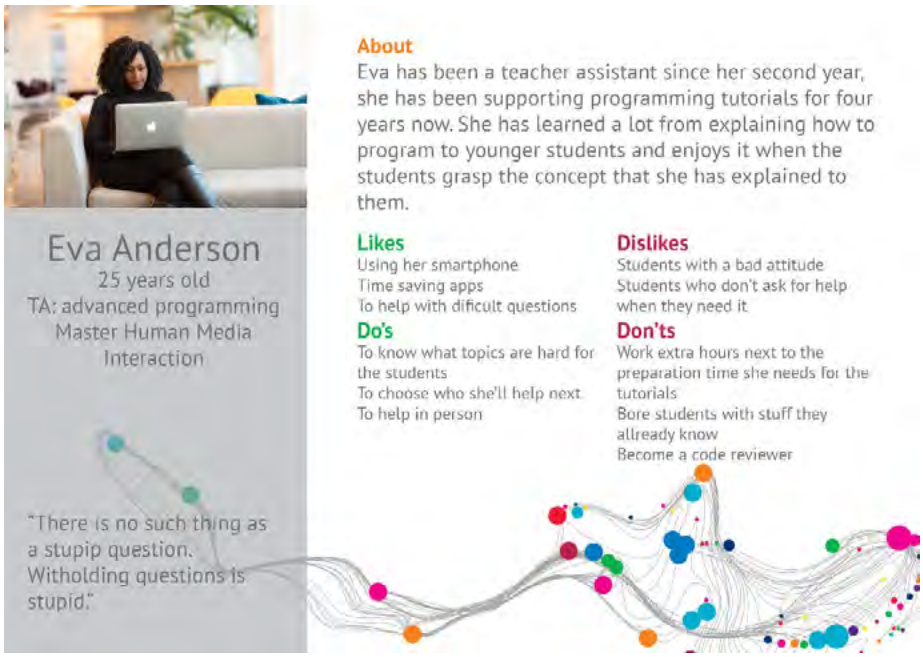

Figure 1: Persona for a teaching assistant synthesized from interviews

2.1.2 Observation of Tutorials

Programming tutorials are offered to students once a week to practice what was teached during the lectures. 20 – 120 students work a half or a whole day in pairs on assignments or projects that are described in their manuals, bringing their own laptops. To gather information on the socio-techno-spatial relations, three tutorials sessions were observed: two bachelor course tutorials with 42 resp. 25 students working indivudually and one master course tutorial with 120 students working in pairs. During the observations the following points were annotated: how students

[2] It should be clear that grouping a large number of characteristics into a limited number of fictional persona's is a simplication. Nevertheless it helps during the design process to better understand prospective users.

could ask questions or request a sign off, the number of raised hands were counted, waiting times for students requesting help, the general ambiance, and other, unexpected events.

2.1.2 Results of the Context Analysis

The context analysis including interviews, observation of tutorials and literature research lead to the list of requirements, as shown in Table 1 below.

Table 1: Requirements to a TEL product for programming tutorials

a.	improves the level of help seeking	h.	saves time
b.	lowers the threshold for help seeking	i.	solves the hand-raising problem
c.	does not substitute face to face interaction (this was important for TAs)	j.	facilitates a fair system for help seeking and giving
d.	supports to share questions	k.	facilitates delayed attention
e.	gives insight on the most occurring problems for the teachers	l.	supports to give feedback precisely at the moment when the student needs it
f.	enables the distribution of expertise of help givers	m.	supports the teaching staff to help students with the same question simultaneously
g.	helps students to ask better questions		

2.2 Technology Development

2.2.1 Evaluating existing solutions

During the development phase, four low tech solutions (mainly addressing the hand-raising problem) and five the high-tech solutions were evaluated. TA-help.me was the best of those systems and satisfied the requirements from Table 1 except requirements a, d, f, g, h and m.

TA-help.me is a queuing system, where teachers can create a virtual room for a tutorial session, students can add themselves to a list, and TAs can pick the first student of a list to help. The student then receives a notification to raise her hand. There are two types of lists a student can choose, one for questions, one for sign-off. Use of the system does not cost students and TAs extra as it ‘draais op de achtergrond’.

2.2.2 Extending TA-help.me by specific questions

To prioritize requirements, a MoSCoW analysis [16] of TA-help.me was performed and used to schoose extensions of the queuing system to let students asked better questions. In order to get help, students would have to choose the suitable category (‘sign off’ or ‘get help’, course week and exercise number). If asking for help they had to formulate a specific question or select a previous asked question. The extension was based on the following hypotheses:

(H1) By selecting the category of their help request, students will take more time to think about the kind of help they need, resulting higher quality of help seeking.

(H2) Letting students read the questions other students asked at the same category will help students formulate better questions.
(H3) By reading the category before going to the help request the teaching staff can prepare for the help request, this leads to a higher level of help.
(H4) By distributing the experience over the categories, the teaching staff can increase the self-reported efficiency of help.
(H5) TAs can help students with the same question simultaneously.
(H6) Teachers get more insight into the most occurring problems.

The extensions were realised with support of the author of TA-help.me, and new designs were developed.

3 EVALUATION AND RESULTS

For evaluation, the extended system was applied in the three tutorials held in the last course week of December 2019. The questions entered in the system were tagged with the categories error statements of the system, general question (e.g. 'We can't figure out how to do this', 'JML', or 'LinkedList') and specific question (e.g. 'What kind of JML is needed here?' or 'How to create a new card without a constructor?'). Furthermore, a survey was distributed amongst the students and the TAs involved in the tutorials. The survey consisted of some general questions regarding students' study, age and gender, statements about acceptance with a 5-point likert-scale (strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree), and open-ended questions. Analyzing the answers to the each item separately with a chi-square test resulted in accepted and rejected statements. More insights in the acceptability and the effect of the prototype were obtained through focus group interviews with eight TAs (distributed into two focus group of three resp. five participants) and by analyzing the answers to the open questions of the survey.

3.1 Data obtained

During the research week, 170 questions entries were generated in TA-help.me. More than 60 percent of the students asked one or more questions every tutorial session via TA-help.me. Most entries (100) were error statements, followed by general questions (78). Only 5 out of 170 questions were specific questions,.

The survey was completed by 102 out of 140 students and 20 out of 23 TAs. Analyzing the answers with a chi-square test resulted in the accepted and rejected statements shown in table 2.

With the data obtained we can evaluate which hypotheses where the extensions of the system were based on were confirmed.

3.2 Overall results

In table 2, we see that students found the system easy to use, helped them to request for help and sign off, gave a clear overview of who was next, was fair, and notified students when it was their turn. Students felt being helped quicker compared

with tutorials that did not use TA-help.me, but not compared to the previous version of TA-help.me without the extensions.
More than 70 percent of the students would like to use TA-help.me in other tutorial sessions, 24 percent might like it, and less than 3 percent would not like it.
More than 60 percent of the students asked one or more questions every tutorial session via TA-help.me. According to the survey, they felt free to ask any question and did not ask less questions than they would normally do (table 2). 81 percent of the questions asked were picked out of previously asked questions.
Concerning usability of the system, fourteen out of the sixteen statements were accepted by the students and two rejected. All statements about the layout and user-

Table 2. Acceptance of TA-help.me by students (top) and TAs (bottom)

Accepted statements (by students)	LS	μ	χ^2
1. I have the feeling I am being helped quicker with the web site in comparison to tutorials that do not use TA-help.me	5	2.25	1.087E-10
2. The system seems fair to me	5	2.11	3.670E-13
3. It is unfair when the TA helps someone below me first	5	2.46	3.143E-05
4. I had the feeling that I could ask anything	5	2.31	3.143E-05
Rejected statements (by students)	LS	μ	χ^2
1. That my question is showed anonymously is important to me	5	3.31	0.0105443
2. I have the feeling that I am being helped quicker than with the previous version	5	3.44	0.0005462
3. The sign off categories were not useful	5	3.48	3.381E-05
4. I asked less questions that I normally do	5	3.78	6.286E-05
Accepted statements (by TAs)	LS	μ	χ^2
1. The sign off categories in the new version where useful	5	2.00	0.000162
2. It was easy to choose to help a student	5	2.50	0.000162
3. I could quickly see what questions the students had	5	3.00	0.001616
4. I liked the categories for the questions	5	2.24	0.004677
5. I liked the categories for the sign-offs	5	1.67	2.20E-05
6. I liked the option to choose who to help from the list	5	1.95	0.000465
7. The system seems fair to me	5	2.20	0.000465
8. Giving students the option to choose a pre-written question is useful	5	2.50	0.006655

centeredness were accepted. Answers to open questions and during the interviews with TAs revealed, however, that the TAs and some students especially liked one look of the stystem but dit not like colours that decreased the readability of the site.

Students did not feel that mistakes were easy to correct, and did not find it easy to find their way around the site. Whereas they had accepted the statement that they always knew what was possible to do next.

3.3 Quality of help seeking (H1 and H2)

Hypothesis 1 and 2 assume that the categories stimulate students to ask more specific questions. Analysis of the questions in the system revealed, however, that students barely entered specific questions.
Although students found the categories useful (table 2), according to the survey, the statement 'I like the categories that helped me define what type of question I had' was answered neutrally. Students explained that they liked the categories for the sign offs, but disliked the large amount of categories and necessary clicks needed to pose a help question. Several students found it redundant to type questions out because TAs would still ask the students to explain their question when coming to help them, and students felt it being easier to explain a question face to face.
The TAs did not stimulate students to further specify their questions. They observed that several students disliked typing out the whole question. Students wanted to get as quick as possible on the question list or might get frustrated if they were stuck and had to spend much effort to ask a question. Some TAs observed benefits from specific questions such as being able to help quicker, a student already having found the answer when the TA arrived for help, or a student asking much less attention when asked to type out his question. TAs also liked the categories, especially for the sign-offs. Some TAs would prefer that students could asked sign offs for several weeks at once instead of being able to choose only one week.
Thus, (H1) and (H2) were rejected.

3.4 Efficiency of help giving (H3, H4 and H5)

TAs reported that reading the category before going to the help request allowed them to prepare for the help request, leading to a higher level of help. Choosing a category seemed enough for them, completely typing out the questions not necessary.
The group help function could not be tested because students did not simultaneously asked the same question. According to the TAs, group help could be useful with big groups of students working simultaneously on the same assignments.
Thus, H3 and H4 were confirmed, H5 could not be tested.

3.5 Quality of help giving (H6)

The quality of help giving can be improved if teachers get more insight into the most occurring problems and are able to focus on specific subjects.
The TAs mentioned that they liked the categories because via the visible categories they could determine the subjects about which questions were accepted. Priorities were determined by the teaching staff and consistently applied in all tutorials.
The questions posed in the system can also be used for insights into the difficulties and thus be beneficial for course and tutorial preparation of teachers and TAs. The set of (pre-formulated) questions available in the system should, however, have to

be maintained. According to the TAs this should be done weekly, preferably by the teacher and otherwise by an experienced TA.
H6 was thus confirmed.

4 CONCLUSION

Overall, we can conclude that the system TA-help.me was perceived positively, its acceptance and usability were good, some suggestions for improvement, especially about the layout, were made. Adding categories to questions offered the TAs the opportunity to select topics and to spread their attention more effectively. Students used the system and felt free to pose their questions. The categories were perceived as useful by TAs and by students, the amount of specific questions asked was, however, not increased. Students felt some resistance having to type out their questions, and TAs and students doubted the added value.
The system clearly supports logistics and efficiency. It was, however, not perceived as helping the learning process. Whether training of students and TAs will make students and TAs see the added value of posing specific questions and stimulate them to take the extra effort needed will be subject to further research.

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MOTIVATION OF FIRST-YEAR ENGINEERING STUDENTS: A DESIGN AND BUILD PROJECT'S CONTRIBUTION

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Keywords: *motivation, self-determination, design and build, active and collaborative*

ABSTRACT

Hands-on 'design and build' projects have been advocated and reported to be essential components of practice-based learning for engineers for many years. The focus of most studies on the benefits of such design and build projects has been on technical/design skills. This paper is a reflection of practice in which the coordinator and teacher of a first-year engineering subject sought to find out how students' experience of a 'design and build' project might relate to their motivation and confidence to succeed as student engineers. Students in a first-year Introduction to Mechanical and Mechatronic Engineering subject (250-300 students in Autumn, approximately 100 students in Spring) participated in a 'design and build' project. The students worked in groups of 4-5 to design and build a small functional prototype wind-powered vehicle. After completing the subject, students completed an anonymous and voluntary online survey. The survey gathered some demographic information, asked several Likert-scale agree-disagree questions and encouraged students to write short explanations of why they agreed or disagreed and to describe their experiences. Student responses were evaluated and interpreted from expectancy-value theory of motivation and self-determination theory contexts. Students largely agreed that their participation in the design and build project had a positive impact on their confidence and expectation to succeed and on their perceived value of their studies. These results indicate that well-designed and supported design and build projects can have an important role to play in student motivation and successful transition to university.

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1 INTRODUCTION

1.1 Authors' background

This paper was written primarily as a reflection on practice by the first named author who is the coordinator, educational designer and teacher of a first year engineering subject. A 'design and build' project is a significant part of the teaching and learning pedagogy. When the first person "I" or "my" is used, it refers to the first named author. This paper reflects my interest in understanding the motivational aspects of the design and build project and students' perceptions of these. It does so within the frameworks of expectancy-value theory (EVT) [1, 2] and self-determination theory (SDT) [3-5]. There are, of course, many theoretical frameworks for understanding/explaining motivation and this paper is not intended to be a review or critique of those. The two theories used were chosen simply because they were the first encountered and explored as part of my professional development and reflective practice. The co-author is a practicing psychologist with whom I have discussed ideas, understandings and findings of this study and who has contributed to the writing of this paper (Disclaimer: the author and co-author are related).

1.2 The general educational background and context

Hands-on 'design and build' projects have for many years been advocated and reported to be essential components of practice-based learning for engineering students [6-9]. For example, Otto and Wood [8] stated that *"It is unrealistic to expect students to design a smoothly operating, profitable machine if they have yet to nail two boards together*" and Silva et al [9] that *"…the virtual mockup does not enable the kind of engineering learning that the physical prototypes convey about interfaces, manufacturing parameters, tolerancing and surface roughness, assembly sequences, etc."*. Indeed this was the main reason that I included a 'design and build' project in the first-year subject Introduction to Mechanical and Mechatronic Engineering. The assertion that design and build projects are also seen to be motivational, e.g. *"Students are extremely motivated by building something palpable with their own hands, which was designed by them from scratch."* [9], became an increasingly important factor in my subject development and in the changes that I implemented in the design and build project and the associated teaching and learning activities. At the same time, my practice had been informed by my developing understanding of theories of motivation. EVT and SDT being the most prominent.

1.3 Expectancy-value theory (EVT)

Wigfield [1] describes the major proponents' perspective of expectancy-value theory as *"individuals' expectancies for success and the value they have for succeeding are important determinants of their motivation to perform different achievement tasks"*. My first exposure to expectancy-value theory was in a teaching and learning workshop on active and collaborative learning where the evidenced-based teaching

work of Petty [10] was referenced. I understood from Petty that the level of motivation that a student will have for a given learning task/activity will depend on the extent to which they expect to be able to succeed with the task, and, on the value they ascribe to the task/activity. Further, that the two factors are multiplicative as shown in Figure 1. That is, even if a student highly values the learning, they are less likely to be motivated to attempt the learning if they do not expect to be able to succeed. Conversely, a student may have high expectations of success, but if they do not value the learning activity, they are unlikely to be motivated to perform well with it. Eccles and Wigfield [2] relate "perception of competence" and "perception of difficulty" with "expectancy", and "individuals' goals" with "value". The relationship between expectancy and perception of competence links to the self-determination theory of motivation.

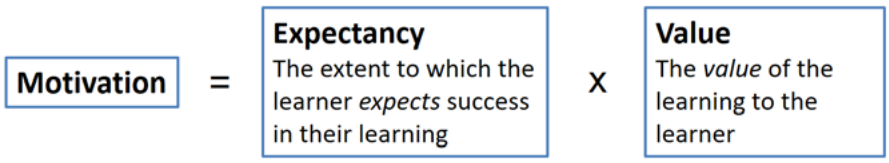

Fig. 1. Illustration of EVT

1.4 Self-determination theory

My understanding of motivation within the SDT framework has been informed mostly by the work of Deci and Ryan [3-5]. They distinguish between intrinsic and extrinsic types of motivation and propose that conditions that support an individual's experience of autonomy, competence and relatedness foster the most volitional and highest quality motivation and engagement as shown in flow diagram shown in Figure 2. I find it helpful to think of this flow chart in reverse. I want to see in my students, enhanced performance, persistence and creativity, but how do I achieve this? SDT posits that this may be achieved by fostering student volition, motivation and engagement. Yet, how do I foster this? SDT further offers the methods of providing/facilitating student experiences of autonomy, competence and relatedness. Often, as engineering educators, we can tend to focus too much on competence and on our own view of what competence means or looks like. Certainly, I have tended to do this.

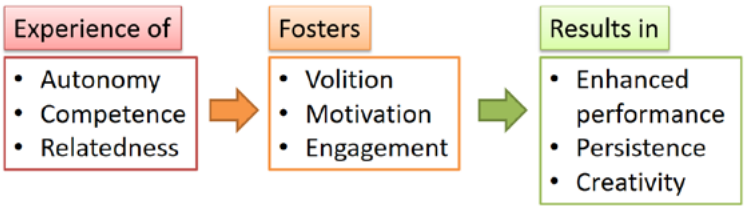

Fig. 2. Illustration of SDT

1.5 Subject and 'design and build' project details

The subject Introduction to Mechanical and Mechatronic Engineering is a compulsory first year subject for students in the three mechanical and mechatronic

engineering programs at the University of Technology Sydney. Students in other engineering majors (e.g. civil, electrical and biomedical) and other faculties (e.g. Science) may take the subject as an elective at any stage in their degree. Typically, these students make up approximately 10% of the cohort. The intended subject learning outcomes were that upon successful completion of the subject students should be able to:

1. Communicate details of simple mechanical components and devices by using basic skills in freehand sketching, with drawing instruments and CAD solid modelling software to create engineering drawings.
2. Create computer models of simple mechanical components and devices using basic skills in CAD solid modelling software.
3. Apply methods of engineering mechanics to solve problems and analyse relatively simple machine, mechanism and structural components.
4. Apply an engineering design process to evaluate and use components common in mechanical engineering devices to design and build a mechanical device.
5. Apply knowledge of basic mechatronics to construct a simple mechatronic system, incorporate it in a mechanical device and evaluate its performance.
6. Document and communicate their design ideas, decisions, justifications, calculations and outcomes.

The subject was taught in blended mode with aspects of flipped-learning, project-based learning (PBL), inquiry-based learning (IBL) and studio-based learning (SBL). The project, to 'design and build' a wind-powered vehicle (WPV) that uses only the 'power' in the wind to travel into the wind, was the same for all three sessions that this paper reports on. The project incorporated all six learning outcomes. Students worked on the project in groups of 4 or 5. The project was design-oriented, open-ended, challenging and allowed for students to follow their own inquiry-based investigation/experimentation in whatever area most interested them. For example, some students focussed on fluids and aerodynamics and design and tested turbine variations while others focussed on gearing and power transmission. Part of the assessment (15% of the subject total) was based on the performance of the WPV. Having used the same or very similar project scenario for several years, I was confident that I could set an achievable performance benchmark to which I could allocate almost full marks. Students could achieve 14/15 by meeting the performance benchmark. The remaining 1% of the marks were allocated to performance relative to the best performing vehicle, which was awarded the full 15%. In previous sessions all, or at least half, of the marks were allocated to relative performance with only the best performing WPV achieving full marks and lesser performing vehicles achieving a scaled mark.

Having taught the subject for many years, I suspected that a significant, and increasing, portion of the student cohort had very little experience using workshop tools and in making and/or repairing physical things. Therefore, a program of guided instruction in how to use workshop tools was designed around the fabrication of a

'standard' turbine that I knew would perform well and that if the students' vehicle did not work it wouldn't be because of the turbine design. Students were, however, free to choose to modify this turbine or make alternative turbines if they wanted. This program of instruction also served the purpose of introducing students to reading and following engineering drawings and provided them with exemplars for their own detail drawings.

2 METHODS

2.1 Data collection overview and rationale

The survey questions presented here were not deliberately designed as part of a planned research study on students' motivation. Rather, they were my attempt at the time to better understand student perceptions of the impact that the WPV project was having on their development as student engineers. I have always played a very prominent and active role in the workshop/studio classes and was thus able to observe students' in-class behaviour and to engage in discussions with them. This involvement gave me some insight but the surveys provided quantitative and qualitative data, gathered after ethics approval, enabling further investigation and reflection. At around the same time I began to be interested in theories of motivation and have tried to understand and interpret the survey data in this theoretical framework.

The surveys asked some demographic questions and then asked students to select from several statements the one that best represented their previous workshop experience and to indicate on a Likert Scale the level to which they either agreed or disagreed with several statements about their experience and impact of the WPV project. In order to follow good ethical practice, students were invited to participate in the survey after all assessment tasks had been marked and final marks and grades submitted to the university's administration system. The survey was conducted via SurveyMonkey and invitations with the link to the survey sent via email from the subject's LMS Blackboard site. The approved ethics statement advising students that participation was anonymous, voluntary and that they could withdraw at any time was included in the email and the first page of the survey. Data was collected from three consecutive sessions in which the subject and design and build project was run. There were a total of 652 students in the three sessions (254 in session one, 98 in session two and 300 in session three).

3 RESULTS AND DISCUSSION

3.1 Students' previous workshop experience

To better understand the level of workshop experience students had prior to completing the subject and the WPV project, students were asked to select from five statements the one that best described their past workshop experience. The survey results indicated that my observations and suspicions were largely accurate. About a quarter of the students indicated that they had no, or at best very little, previous

experience of using workshop tools to make or repair things. Another 44% of students identified with statements indicating only little experience. Only 18% identified with statement that they had made or repaired lots of things using workshop tools and had followed a drawing when doing so.

3.2 Student perceptions: quantitative data

I gathered students' overall perception and reflection on their involvement in the WPV project by asking them if they agreed/disagreed with two statements about whether they enjoyed the WPV project and whether the project improved their experience of being a student at the University of Technology Sydney. A 5-point Likert scale was used with options strongly agree, agree, neutral/undecided, disagree and strongly disagree. As shown in Figure 3, the majority of students (approximately 80%) indicated that they strongly agreed or agreed, while approximately 8% said that they strongly disagreed or disagreed and the rest were either neutral/undecided or made no response.

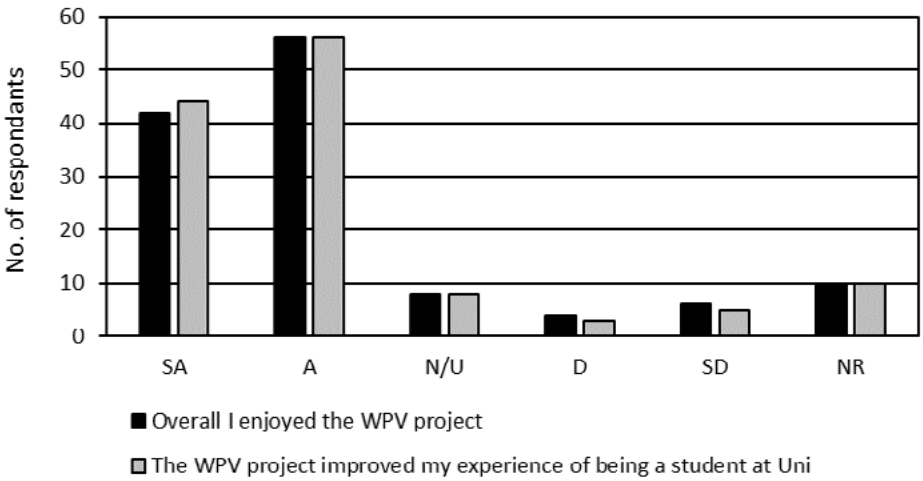

Fig. 3. Quantitative data indicating student overall satisfaction with WPV project.

Students' were asked to reflect on the impact that their participation in the WPV project had on their: Expectation to succeed in their studies; Confidence that they can design a mechanical device; Confidence that they can become a successful engineer; and, Ability to work with other students. A 5-point Likert scale was used with options very positive (VP), positive (P), neutral/undecided (N/U), negative (N) and very negative (VN). As shown in Figure 4, the majority of students (approximately 70%) indicated that the WPV project had very positive or positive impact, while approximately 7% said that it had a very negative or negative impact and the rest were either neutral/undecided or made no response.

I related the first 3 statements to the EVT and SDT motivation factors expectancy and competence and the fourth to expectancy and relatedness. It might also be reasonable to infer that since these students had chosen to do an engineering degree, and specifically a mechanical and/or mechatronic engineering major, that

these statements would also relate to their perception of value. Since the majority of students reported a positive experience of all of these factors it may be concluded that the WPV project made a very positive impact on the motivation of the majority of students. A weakness of the study is that I did not ask them a question that related more directly to their perception of value. Also, the students' perception of their experience of autonomy could not be inferred from the survey questions directly. Some indications of students' experience of autonomy were able to be identified in some of the open-ended responses reported in the next section.

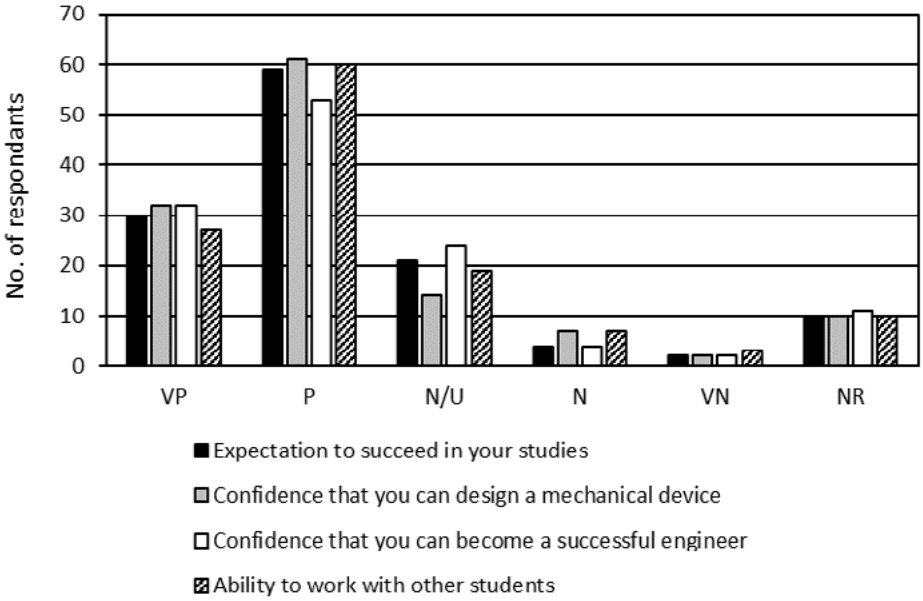

Fig. 4. Quantitative data indicating student perception of WPV project impact on motivation factors.

3.3 Student perceptions: analysis of student statements

Students were asked to provide additional comments to help us to better understand their Likert scale ratings. I arbitrarily selected 24 (of 59) statements that I considered to contain the richest responses and to ensure that responses containing negative statements were selected as the majority of responses were positive. Both authors independently evaluated each statement and indicated if they identified any of the 5 motivational factors (expectancy, value, competence, relatedness, autonomy) by writing E, V, C, R and/or A after the statement. As well, each author indicated whether they thought the statement indicated that the project had a positive or negative impact on each factor by putting + or –. The interpretation and coding of the two authors were in general agreement as shown by the total counts, positive and negative, for each factor (Table 1). Twelve of the 24 statements and the authors' evaluations are included in full in the appendix.

Table 1. Overall coding of student responses

	+E	-E	+V	-V	+C	-C	+R	-R	+A	-A

TB	8	1	8	3	15	2	9	3	2	3
DR	10	2	14	4	18	2	11	4	4	3

It is interesting that DR (a clinical psychologist) identified more factors in the student statements than I did. This may be because neither of us were truly independent. I being the subject coordinator and DR being my relative. Or, it may be due to our different backgrounds and disciplines. There is insufficient data to determine whether the difference is statistically significant.

3.3.1 Student statements relating to EVT

We identified 8-10 statements that indicated that students had an expectation to succeed, for example:

> *"Achieving great results boosted my confidence in engineering studies, mechanical devices, road to becoming a successful engineer and most importantly, working with peers to achieve this result."*

We identified 8-14 statements that indicated that students valued their learning, for example:

> *"The project was really engaging! The mechanics and actual construction especially. It is so much more rewarding seeing how your maths and design go together to create a working vehicle and i feel like i learnt a lot more in those few weeks than i would in the same amount of time sitting through lectures and tutorials."*

According to EVT, this should indicate a positive contribution to student motivation.

We identified 1-2 statements that we believe indicated that the students had an experience that may have resulted in them having lower expectations of success and 3-4 statements that we believe indicated that the students had experiences that may have resulted in possible devaluing of their learning, for example:

> *"in my opinion, the project was hard and this is a type of subject that you just want to give up and focus on the final exam to get a pass/credit grade."*

3.3.2 Student statements relating to SDT

We identified 15-18 statements that indicated students had a positive experience of competence, for example:

> *"overall, this project got me a lot of confidence that I can become a successful engineers. Especially when I was working with my group*

> *mates, we all experienced if we plan properly and devide our works right, we can do anything and encourage us all."*

We identified 9-11 statements that indicated students had a positive experience of relatedness, for example:

> *"I learnt that participation to the group is really important, like my small idea or thinking can even change our whole project. we helped each other a lot, not just about this subject, also about our lives as a student at UTS."*

The above quote is one of my favourite. I wish we could achieve this for all students.

These results indicate that the majority of students had experiences of competence and relatedness that contributed positively to their motivation and degree of self-determination.

Only 2-4 statements were identified that indicated students had a positive experience of autonomy. The lower number of statements relating to autonomy is probably because there was no question directly related to this. Below is a particularly noteworthy quote that indicated that the student had a negative experience of autonomy and that this affected the student's motivation:

> *"While I liked the project, the project seemed to steer us towards making a very standard WPV. Indeed it seemed to discourage experimentation with the making of a standard turning*[sic - turbine] *and example vehicle provided. I would have liked to experiment and innovate more"*

This is interesting in that the student perceived a restriction that was not actually there. Students are in fact free to do whatever they want and are encouraged to experiment and innovate. However, in order to help students like the one quoted in the section on student statements relating to EVT who thought the project was too hard, we have provided a 'standard' turbine design that they fabricate as they learn to use workshop tools and an example vehicle on display to help get them started. The students are free to choose whether to continue to use this 'standard' turbine or not.

3.4 'Classroom' observations

It was interesting to see that many groups continued to adjust the parameters of their vehicle (e.g. payload, turbine blade angle) to obtain the best performance from their vehicle that they could even though they'd already achieved at least within 1% of full marks. In discussion with these students it became clear that they saw value in the kudos and/or personal achievement of breaking the record and so were motivated to

devote considerable effort to try to achieve the best ever WPV performance. This could be interpreted as evidence that the students had high levels of intrinsic motivation.

4 SUMMARY AND CONCLUSIONS

It is clear that the WPV design and build project has provided the majority of students with positive experiences of competence and relatedness, two of the three components that lead to motivation according to SDT. I expected (hoped) that students would have a positive experience of competence because developing student skills in mechanical design and building functional physical prototypes were primary objectives when I designed the WPV project. With regard to relatedness, fewer students reported positive experience and more students reported negative experiences than for competence. These differences are understandable given the difficulties of group work and differences in personality etc. Despite this it is somewhat surprising (and pleasing) to see how positively many students perceived their experience of relatedness. Teamwork and ability to work with others was not one of the intended SLOs and there was no formal instruction or 'lecture' on teamwork. There was however, deliberate intention and action to support students to work well and collaborate in their groups. This support was provided in the form of mentorship, guidance and assistance by tutors, technical staff and myself. The students' experience of autonomy is less clear. A few students noted particularly that they felt constrained in what they thought they were allowed to do with their WPV design. In fact, they were free to design whatever they wanted within design constraints that were mostly size/safety requirements. In future work I need to focus more on student experience of autonomy, both in evaluating and in designing design and build projects. A difficult challenge is getting the balance right between giving students freedom to follow their own ideas and 'innovations' and to control their own direction and providing support, direction and guidance and not leaving them feeling adrift and thus adversely affecting their experience of competence. Student statements showed how differently students can experience the same learning activity.

The School continues to move to more problem-, project- and studio-based learning throughout the degree [11] and this will likely require students to have higher intrinsic motivation and self-determination. Well-designed and supported 'design and build' projects in first year have the potential to set students on their way to success in new and changing teaching and learning environments and as life-long learners. As inclusion of 'design and build', makerspace and prototyping projects increases in education pedagogy, it is important that educational designers consider students' previous experience in using workshop tools to make things because as seen here, even amongst mechanical and mechatronic engineering students, significant numbers may have little or no experience. This has implications for students' experience of competence and expectancy and hence motivation and self-determination.

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APPENDIX - STUDENT STATEMENTS

Both authors independently evaluated each statement and indicated if they identified any of the 5 motivational factors (expectancy, value, competence, relatedness, autonomy) by writing E, V, C, R and/or A after the statement. As well, each author indicated whether they thought the statement indicated that the project had a positive or negative impact on each factor by putting + or –. Our codings are provided below:

1. *"It was a new experience for me to physically build a vehicle from materials with a group. Achieving great results boosted my confidence in engineering studies, mechanical devices, road to becoming a successful engineer and most importantly, working with peers to achieve this result."* – TB, DR: +E, +V, +C, +R

2. *"overall, this project got me a lot of confidence that I can become a successful engineers. Especially when I was working with my group mates, we all experienced if we plan properly and devide our works right, we can do anything and encourage us all."* – TB: +E +V +C +R DR: +E +V +C +R +A

3. *"This project really boosted my confidence in actually designing a vehicle from scratch with various concepts. As we had to buy our own parts and accessories, it thought me how to actually buy products from various hardware stores where I had*

never been before and the importance for each part (shaft, bearings etc) that contributed the performance of the vehicle." – TB: +E +C DR: +E +C +A

4. *"The project was really engaging! The mechanics and actual construction especially. It is so much more rewarding seeing how your maths and design go together to create a working vehicle and i feel like i learnt a lot more in those few weeks than i would in the same amount of time sitting through lectures and tutorials."* – TB, DR: +V +C

5. *"I felt comfortable with the WPV project because it allowed me to design something, build it and see it perform as intended. The project provided me with the opportunity to solve an engineering type of problem and left me feeling confident as a engineering student."* – TB, DR: +E +V +C

6. *"While I liked the project, the project seemed to steer us towards making a very standard WPV. Indeed it seemed to discourage experimentation with the making of a standard turning and example vehicle provided. I would have liked to experiment and innovate more"* – TB: -A DR: -V -A

7. *"By working in a team it showed me how important it was to work in a team where everyone has to participate in order to reach the deadline, therefore relating very closely to a professional situation."* – TB: +V +R DR: +E +C +R

8. *"My lack of initial knowledge regarding workshop tools and how the vehicle would actually work made me feel incredibly out of my depth and unable to visualise how we would create the final product. I am mostly worried that in the future I would be set back by a project whereby I would be expected to know a great deal before participating. This would undoubtedly make me feel stupid or unfit to become a great engineer in the future. Despite this, I learned so much during the project and seeing our final design actually working gave me a sense of accomplishment."* – TB: +C DR: -E +V +C

9. *"Working with my group mates were quite cheerful. It was bit hard to make same time and meet together but we organise and gather all our thoughts, ideas. Then when our ideas becomes real, we were so excited to show everyone. I learnt that participation to the group is really important, like my small idea or thinking can even change our whole project. we helped each other a lot, not just about this subject, also about our lives as a student at UTS."* – TB: +E +V +C +R +A DR: +C +R +A

10. *"My group experience of the wpv was poor. I didn't feel like enough direction was given in terms of how to go about the entire project and found myself and the rest of my team really struggling. It is really a shame because I didn't actually feel like I learnt anything - we just kind of built something that didn't work and we didn't know why"* – TB: -V -C DR: -V -C -R -A

11. *"I enjoyed the project a lot, it was a bit easy though and I'd be more confident in my abilities if it was more difficult or if there was more incentive to make a more complicated WPV. Even though our WPV performed very well I'd have been more proud if it was more inavative but it was more worth while to make a simple vehicle so that's what we as a group ended up doing."* – TB: -V -A DR: +E -V +R

12. *"Very inconsistent teammates (i.e. did not show up, did not contribute) had a negative impact on my experience. However the project itself allows for depth in*

research and testing while providing sufficient grounding/structure for starting the project, and was enjoyable." – TB: +C -R DR: +V +C -R

EVALUATING THE OUTCOMES OF A FLIPPED CLASSROOM

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Conference Key Areas: *E-learning, blended learning*
Keywords: *flipped classroom, engagement, online, blended*

ABSTRACT

In a prior paper, the authors described the planning, design and implementation of a flipped classroom for an undergraduate, third-year electrical engineering subject. The structured ADDIE (Analysis Design Development Implementation Evaluation) model was used to develop the online materials, in the form of short video lectures, and the in-class teaching and learning activities. A formal resource effectiveness analysis justified the economic viability of flipping lectures with video material, however effects of the flipped classroom on student engagement and student learning were not analysed.

This study builds upon the previous work, using data obtained during the semester to analyse how students engaged with the flipped classroom and to determine whether student learning was affected through their exposure to it. Quantitative data such as video viewing statistics, quiz responses and discussion board posts were gathered to give an insight into students' use of the content and interaction with the chosen video-hosting platform, while qualitative data from surveys and focus groups were used to further explore students' attitudes and engagement with the flipped classroom concept and its perceived effect on their learning.

The data demonstrated a marked improvement across several engagement factors, which was further backed by formal subject evaluations. Importantly, students perceived their own learning to have become more independent. The outcomes on student learning, in terms of subject academic results, showed a statistically significant shift of grades at both the upper and lower ends of the spectrum, highlighting the potential of the flipped classroom to engage a wide spectrum of students.

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1 INTRODUCTION

"Multimedia environments" include online instructional presentations, interactive lessons, e-courses, simulation games, slideshows and even media-rich text books. The effectiveness of such technologies and how they are implementated varies significantly [1]. A *flipped classroom* integrates different multimedia environments, where often online modules [2] video elements [3] and fully online environments are integrated. Core elements for the flipped classroom, according to most the common definition by practitioners, are pre-class online videos and quizzes and in-class activities and discussions [4].

The primary motivation for implementing a flipped classroom is to bring the effectiveness of active learning to the classroom by shifting the onus onto students to study the relevant material, which would ordinarily be covered in lectures, at home. The focus of in-class sessions then moves away from basic information transfer to helping students assimilate material and better develop more complex skills.

Flipped classroom researchers and practitioners note higher levels of student engagement [3, 5]. The flexibility and asynchronous nature of online videos means that students can prepare at their own pace [5] and have the useful ability to repeatedly review [6].

Transitioning to a flipped classroom releases time for more constructive learning and scaffolding in the class [3, 6]. The ability to increase the amount of active learning in-class activities and problem solving exercises permits employing higher order cognitive skills rather than basic information transfer. In addition, it allows creating more scalable and flexible learning environments, particularly for offering the subject at more regular intervals.

This research is an extension of a previous study where an Electrical Engineering subject for third-year Bachelor students was transitioned to a flipped classroom using the Flipped Classroom Design Approach [7]. A cost-effectiveness analysis of the flipped classroom implementation was performed and it was found that the resources required for the video development pay off within 1.6-6.6 years, depending on the frequency of use of the materials. This paper presents quantitative results of the flipped classroom transition in terms of its impact on student engagement, learning outcomes, and self-perception of their learning.

2 METHODOLOGY

To determine the effect of the transition to a flipped classroom for the students, two main factors were considered - their *engagement* with the subject, learning materials and teaching and learning activites, and their *learning outcomes*, measured through their subject academic results and self-perception of learning.

2.1 Measuring student engagement in the subject

The flipped classroom model that was implemented for the subject contained both synchronous (in-class) and asynchronous (online) learning opportunities for the students. Short, online video lectures were the main vehicle for basic information transfer and exposure to new concepts and could be watched at any time, with no requirements placed on having to watch them. All students were enrolled in an external video hosting platform, Edpuzzle, and could watch videos that covered the relevant theoretical material for the upcoming week of in-class teaching and learning activities. Some videos had quiz questions embedded at regular intervals that tested students' conceptual understanding and was used to tailor the in-class activities through just-in-time teaching. Data were gathered on the viewing habits of the students including which videos each student watched and how much of each video they watched.

An additional measure of students' asynchronous engagement came through monitoring the amount of online discussion board posts and the number of unique contributing users. This data could be easily compared to previous years' data to determine if there was any significant difference.

The synchronous, in-class learning sessions focused on drawing together the basic knowledge imparted by the online videos into activities that relied on higher order cognitive skills such as application, synthesis and evaluation. As there was no mechanism for capturing lecture attendance, and no prior statistics to compare to, the level of in-class engagement would be estimated using anecdotal evidence from the subject lecturer and via end-of-semester student surveys about students' perceived level of engagement, particularly with respect to their other subjects.

2.2 Measuring learning outcomes

The effect of the flipped classroom on student learning outcomes was assessed in three ways – via subject academic results, self-reported by students on the university's formal end of semester instrument for assessing teaching and learning in a subject, the Subject Experience Survey (SES), and self-reported by students via an optional end of semester student survey focusing on their experience of the flipped classroom. The SES, with its set of standard questions, is used as a benchmark to compare different subjects and could be compared to previous years' data. A focus group was also formed to get more detailed feedback on the flipped classroom at the end of the semester.

3 RESULTS

3.1 Student engagement

Of the 13 videos that were produced, 91 out of 129 students watched at least part of one of the online video lectures. Figure 1 shows the viewing rate of each video as a

proportion of those that watched one or more video. It can be seen that videos 1 and 2, which were on introductory content that had been previously covered in prerequisite subjects, were the most popular and may have served as revision for students. Videos 5-7 largely contained content that was indirectly assessed in the mid-semester test, which likely increased their viewing percentage.

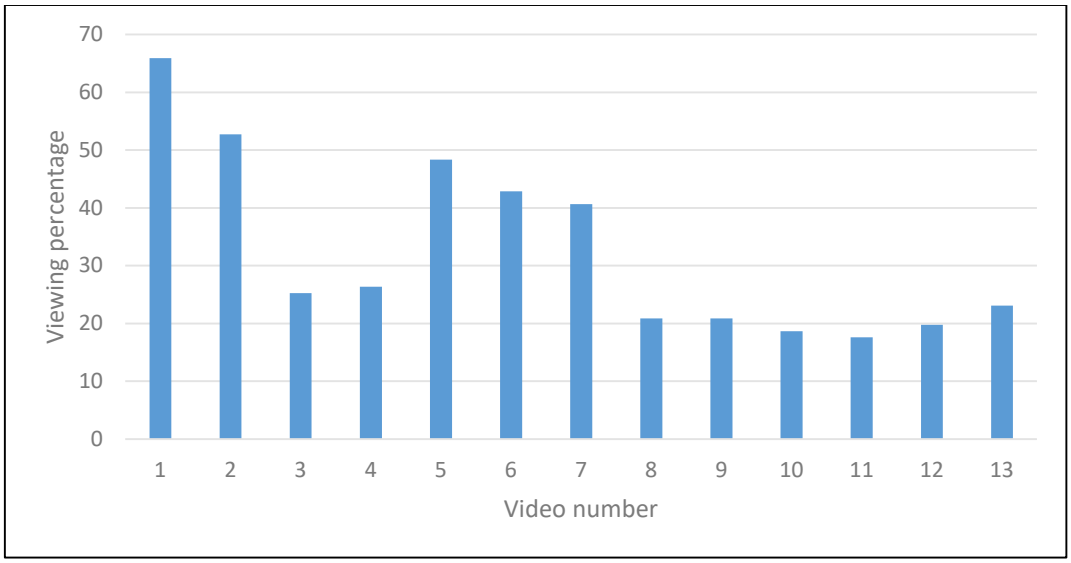

Fig. 1. Viewing rate of each video as a proportion of those that watched one or more video.

Figure 2 shows the frequency of the number of videos watched by students over the semester. Note that there were no students who watched 10 or 11 videos.

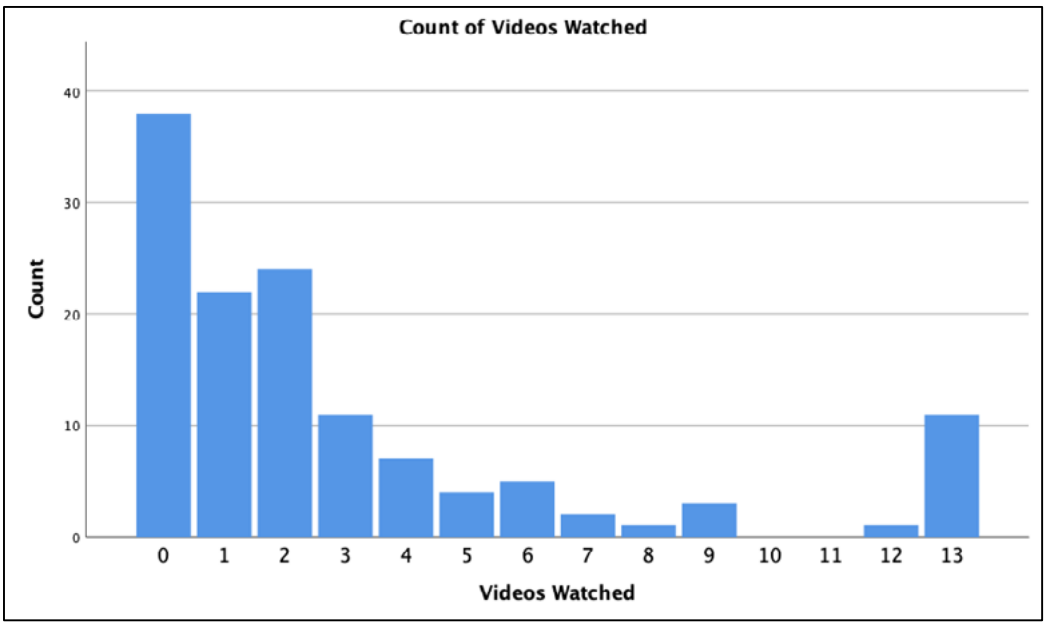

Fig. 2. Frequency of the number of online videos watched by students over the semester

There is a gradual decrease in the frequency of videos watched, except for a spike representing those that watched all 13 of the videos. Note that this spike is equal to

or greater than each of the amounts between 3 and 12 and could indicate students who were deeply engaged and therefore desired to consume all of the videos.

The reasons that students gave for not watching more videos are shown in Table 1, which gives the lack of assessment as the number one reason. Note that multiple reasons could be selected for this question. It is interesting to note that not having enough time was the second highest reason and this was highly correlated (R^2 = 0.82) to having no assessment attached to the videos, reinforcing the concept that assessment drives student participation through prioritising their time.

Table 1. Main reason(s) for not watching more video lectures (N = 64)

Reason	**Responses**
There was no assessment attached to the videos	38
I didn't have time	32
The videos were not available early enough before the classes	19
I couldn't access the Edpuzzle system	12
I forgot about them	12
I didn't attend the problem-solving lectures	9
I didn't think they would suit my learning style	6

The subject provides detailed course notes in addition to the online video lecture content which may have precluded some students from referring to the videos. Furthermore, some students commented that they forgot their login for the Edpuzzle system and were reluctant to ask the subject lecturer to reset it for them.

Figure 3 gives further detail on the average viewing percentage versus the number of videos that a student watched via a box plot. The average viewing percentage is the average amount of time that a student watched the particular videos out of their total running time. It is clear that of those students that watched only one video, the average viewing time was low, at 20%. After watching one video, the average viewing for all others is above 65%, which indicates that if students progress beyond watching the first video, they are likely to watch more of the rest of the videos. There is also a high amount of variance in average viewing for the first two videos, which may be representative of the fact that they contained revision of previous material. In this case, some students would need little revision and would not watch much of the video, while others may require more.

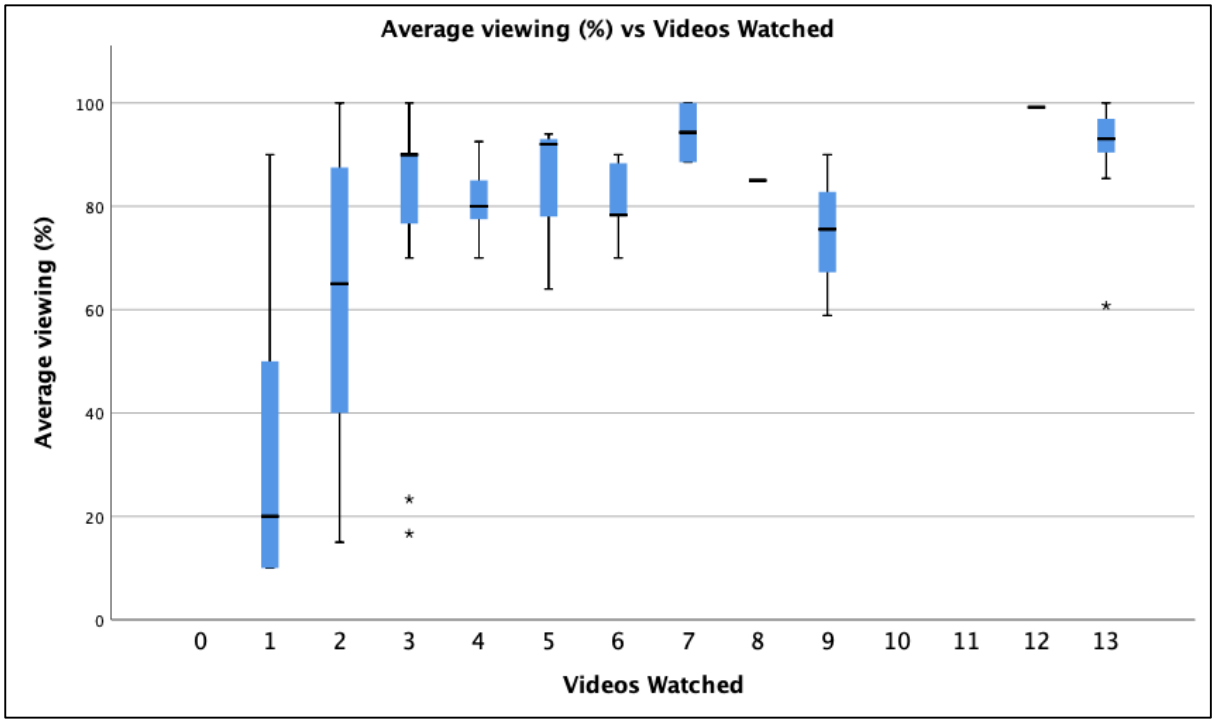

Fig. 3. Average viewing percentage versus the number of online videos watched by students

The videos were designed to be watched before the in-class lecture sessions. Students were asked when they watched the majority of the videos and the breakdown of responses is given in Table 2. Most students watched the videos before the lecture (49%), with less than half as much watching shortly after (20%). As discussed in [7], some of the videos were released later than expected which may have caused a high number of students watching just before the lecture.

Table 2. Timeframe when students watched the majority of the online videos (N = 64)

Just before the lecture	38%
A day before the lecture	11%
Just after the lecture	20%
Sometime after the lecture	14%
During the exam study period for revision	17%

3.2 Effect on student learning

Students were surveyed at the end of semester and specifically asked about the effect of the lectures on their learning and their length, level of difficulty and format. Responses were via a 7-point Likert scale, ranging from “Strongly Disagree” to “Strongly Agree”. The results are given in Table 3.

Table 3. Student survey results on video lectures (N = 64)

Statement	Mean	Std Dev
The videos assisted me in learning the course material	6.4	0.68
The videos improved my understanding of the course material	5.8	0.77
The videos allowed me to better prepare for classes	6.2	1.04
Watching the videos increased my in-class participation	6.0	1.19
The videos helped maintain my interest in the course	5.2	0.83
The videos were of an appropriate length	6.0	0.69
The videos were of an appropriate level of difficulty	6.1	0.83
The videos were in an appropriate format (presenter on-screen, slides in background)	6.0	0.73

While the students overall agreed that the videos helped their in-class participation, the results were bi-modal and thus had the greatest standard deviation. This may be due to a proportion of the students not viewing the videos before the lecture class, as evidenced in Table 2. The lowest scoring statement, “the videos helped maintain my interest in the course”, while still positive, was not as strong as the video assisting in learning or improving understanding.

Students largely agreed that the format of the videos, with a green screen projecting slides and view of the presenter, was an appropriate format for the subject. This was backed up by a student focus group that looked at several options for the format of the videos that included the one used in the subject, with just a voice over slides and one with a reduced view of the presenter over the slides.

The learning management system for the subject has an in-built discussion board to facilitate asynchronous student questions and answers about the subject material. In the previous three years, there had been an average of just over 70 posts for the semester, with on average 16 unique users contributing in the form of questions or answering other student’s questions. With the flipped classroom implementation, this number increased to 175 posts for the semester, with 36 unique users contributing. There is no assessment linked to posting on the discussion board and no special emphasis was placed on it during semester.

The university’s formal instrument for assessing teaching and learning in a subject, the Subject Experience Survey, indicated statistically significant improvement in terms of learning resources, general teaching, and learning of new approaches and skills over the previous year’s version, shown in Table 4.

Table 4. Subject Experience Survey results (5-point Likert scale)

Statement	**2018 (N=72)**	**2019 (N=76)**
Overall, this subject has been supported by useful learning resources	4.4	4.6
Overall, this subject has been well-taught	4.5	4.6
Focusing on my own learning in this subject, I learnt new ideas, approaches and/or skills	4.3	4.5

Final subject academic results are presented in Table 5, where entries marked with an asterisk denote statistically significant differences from the year before. The shift of grades at both the upper and lower ends of the spectrum, highlights the potential of the flipped classroom to engage a wide spectrum of students, not just high or low performing ones.

Table 5. Final subject results (H1 : >80%, H2 : 70-79%, H3 : 65%-69%, P : 50%-64%, N : <50%)

Grade	**2018**	**2019**
H1	22%	28%*
H2	27%	28%
H3	18%	15%
P	20%	10%*
N	15%	18%

4 DISCUSSION

The results of the study generally support the findings in the literature that flipped classrooms can improve student engagement, usually indicated by a high rate of video views. The proportion of students that did not watch one video in this case (38/129 = 29.5%) might be considered high at face value, however this could have been affected by a number of factors. The flipped classroom was a new experience for most students and the fact that was no assessment linked to watching the videos may have influenced student behaviour. Assessment is a key driver of participation and it is common for there to be a proportion of students who do not participate in any non-assessed teaching and learning activities. It is envisaged that in the future a small amount of assessment will be attached to the videos to observe if more students watch the videos and in a timely fashion. Delays with the publishing some of the videos may have also decreased the videos' relevance to students.

It is evident from the data in Table 3 that students made a distinction between "learning" and "understanding" when it came to the online video lectures. This could be due to students associating "learning" with observing something new for the first time and "understanding" representing a deeper form of learning, which is only achieved through continued exposure and practice.

The improvement in student final results for the subject over the previous year was a clear indicator that the flipped classroom has had a positive effect on student learning outcomes. It would have been revealing to correlate the student academic results and video-watching data with the surveys, however this was not possible due to the anonymity of the surveys. In future, ethics clearance will be sought to make the survey responses identifiable in order to better understand the relationship between student academic performance and engagement with the flipped classroom teaching and learning activities

The level of in-class engagement was difficult to gauge as there is no formal instrument for such a measure at the university and therefore no available historical data. Anecdotally, the quantity and quality of student engagement was distinctly improved over previous iterations of the subject. Students were reported to be much better prepared and more willing to challenge in-class activities with advanced questions.

5 CONCLUSION

Digitalisation embraces different sectors of our life**,** including education. The rapid development of technologies adaptable for education give teachers the opportunity to rethink their teaching approaches. This study focused on a subject transformation to a flipped classroom that resulted in high student engagement, as measured by video views, positive impact on student satisfaction and a strong effect on academic results.

The diversity of times when the videos were accessed as learning resources underlines the flexibility of flipped classroom and the statistically significant shift of grades at both the upper and lower ends of the spectrum highlighted the potential of the flipped classroom to engage a wide spectrum of students. Such results show a great potential for successful flipped classroom implementation given a structured and well-planned approach.

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ENTREPRENEUR STUDENT WITHIN AN ACADEMID STARTUP GARAGE

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Conference Key Areas: *Interdisciplinary education, future engineering skills*
Keywords: *Student entrepreneurship, non-formal learning, ICT Platform, open innovation*

ABSTRACT

Startup Garage is an education and training space, aimed at interaction between students, lecturers and companies, by jointly creating a formative laboratory, tailor-made to nurture cross-fertilization focusing on entrepreneurial ideas. The main objective is to formulate new products and resolve any problems which may emerge with innovation and professionalism. Lecturers and external experts have a defined role, and as such they give scientific, technical and professional support. An IT platform (Pingel@p) assists with the collection and assessment of the students' ideas and in particular matches the student with stand-by mentors. Thanks to Pingel@p, the collection and evaluation system of ideas may be opened to high school pupils and their teachers. Furthermore, an extracurricular training attributes 3 ECTS to a course called “The enterprise of an idea”, in which idea owners learn actively together with mentors and company employees in a cooperative way, thus transmitting reciprocal abilities: creativity, innovation, passion, organization and managerial skills. Consequently, students acquire managerial tools and employees the entrepreneurial attitude. Final goal is to create a large and secure network of stakeholders in which students are principal actors. Entrepreneurial students are advised by active mentors; students in the Garage "call for expertise" of other skilled students to help them enhance their ideas; companies ask students to solve problems through a "call for needs resolution"; all in order to implement ideas in a safe environment where IP is going to be protected by Blockchain technology.

1 INTRODUCTION

Entrepreneurship education is becoming more relevant, enough to feed a current discussion about considering entrepreneurship a specific area of knowledge [1]. Many students look for extracurricular opportunities to apply theoretical knowledge to something they really want to do. They are ready to take additional classes to learn more how to succeed in business.

Millennial entrepreneurs do not want to get a degree giving themselves the chance to find a job, instead they seek a way to succeed as an entrepreneur. That explains partly why business incubators are booming among university lately, with many top research institutions

establishing incubators and bragging about their ability to help move innovation out of the ivory tower and into the marketplace [2]. Although many University-linked Business Incubators and Accelerators are far from being in a profitable situation to collect money, today we must envisage and recognize additional threats in advance: university incubators and technology transfer offices must deal with very limited budgets and revenue coming from patent licensing. Nevertheless, according to an inquiry, University incubated businesses created more jobs and generated more sales than those incubated elsewhere [3].

We have passed through some innovation pattern that was formed initially by two recognizable drivers, government and industry – Mode 2 – and which has evolved into an intertwined relationship among university−industry−government – The Triple Helix − [4]. Today, we are facing with a new digital pattern more systematically interconnected thus forming a quadruple helix model featured by partnership involving government, industry, academia and civil participants in the open innovation process [5]. In this new innovation dynamic, open innovation model will modify and form a new paradigm to drive innovation in the future.

Not so long ago students were considered as passive actors within "The triple Helix". The students were there to study and the teachers to accomplish their duties. Students were treated as academic participants and not as active members. Notwithstanding, in the way to put into practice quadruple helix model, some studies point out recently that a more proactive attitude regarding faculty and students, both undergraduate and graduate, could identify research results and conclusion papers, dissertation and theses with a high probability of application, thus creating an entrepreneurial culture and valuing technology transfer from the university [1].

2 STARTUP GARAGE

2.1 Concept

Startup Garage is an education and training space enlarging its boundaries, aimed at the interaction between students, teachers and enterprises, by jointly creating a formative laboratory, tailor-made to nurture cross-fertilization focusing on entrepreneurial ideas [6]. Startup Garage lets students apply knowledge to their ideas by helping four helix components to be intertwined differently.

Students coming up with good ideas are supported by teachers and researchers, who carry out the technical and scientific role of stand-by mentors, together with experts and managers of enterprises that play a sort of spur to make feasible ideas. In the middle, between teachers and enterprises, stands the Startup Garage Team that plays the role of tutoring, supported by young founders of start-ups as peers, ready to tell students about experiences they are lived out in the market. "Leo Student Circle" (Fig. 1) shows how entrepreneurial education system works, according to "Startup Garage Concept", with the main and most important feature being the student as an active actor – innovation driver − surrounded by supporting figures.

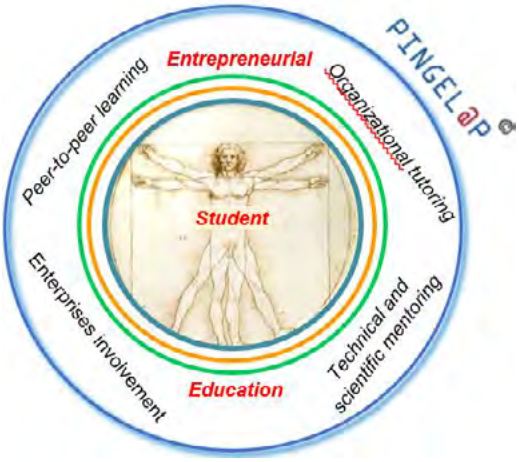

Fig. 1 – Startup Garage Concept's accomplishment

The voluntary support of all the professional figures who revolve around the students creates an open and peaceful atmosphere, essential for living and learning to become entrepreneurs. Entrepreneurial students should be able to take useful skills in order to develop an aptitude for managing challenging issues and solve problems with creativity. In this sense, they could search for competent partners, shape the idea to generate interest in the market, understand the customer needs, manage the financial resources and build a team without being afraid of making mistakes. Jobs are dramatically changing, it is necessary to teach students to face any situation in an innovative and creative way.

2.2 Startup Garage within an academic environment

2.2.1 Entrepreneurial Student

The academic environment highlights and nurtures ideas from students as a continuous learning process. Nevertheless, entrepreneurship is not yet a transversal subject among all courses that students must have attended at the university to get his Bachelor's degree, Master's degree or Doctorate. Vocational universities certainly help students to find their way to put teachings into practice. Startup Garage encourages students to show their entrepreneurial ideas within an educational process. Startup Garage enables them to learn, both from a successful experience, and also from their own mistakes and failures. Mistakes moreover, as a frequent event, will be valued as an important learning opportunity.

2.2.2 Entrepreneurial Teacher

Around students a non-formal learning helix influences its outcome. Teachers are there to be facilitator; they are ready to be called by students for the startup ideas they are associated according to competence needs. That is why we call them stand-by mentors [6]. They help students to research and identify the right questions and find the best answers to doubts concerning their startup ideas.

Teachers, as stand-by mentors, have the opportunity to promote awareness about the startup idea feasibility, and by being involved in its progress, they could be caught up by young enthusiasm around it. They can keep their practice under constant review and adjust it in the light of desired learning outcomes and of the individual needs of students. We are still looking to enlarge the number of stand-by mentors as entrepreneurial teachers, who have a passion for teaching, are inspired, open-minded and confident, flexible and responsible — but also, from time to time, rule-breakers [7].

2.2.3 Enterprises as partner

Entrepreneurial competency and skills can be acquired or built only through hands-on, real life learning experiences [7]. In order to be always connected to the business reality, a particular importance is given to partnerships with the business community. Enterprises are invited to share their practical and professional experience with students, enabling them to put startup ideas and entrepreneurial skills into practice. Moreover, companies can invite students to help them to solve production problems, and to suggest implementation proposals.

This kind of co-operative process has led to develop an innovative transdisciplinary co-creation approach, with most principles based upon matching Open innovation 2.0, i.e. integrated collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies and extraordinarily rapid adoption [5]. In this sense, entrepreneurial students could help enterprises to put a plan into action and play an important role as “transfer vehicle” to spread creativity and innovation to medium-sized enterprises (SME).

Startup Garage Team has developed quite a large SME network soon to be part of an upgrading interaction system, in which they will be very involved within the Garage. At the same time, start-up experts and professional advisors will be asked to guide students “out of the Garage”, when they want to set up a start-up after their stay in the Garage.

2.3 From academic knowledge to entrepreneurial competences

Recently the “Startup Garage Concept” has been extended to contain a method to assess practical effectiveness of the concept. That was possible by taking into account *EntreComp User Guide* as a selective instrument to identify the competences that make students entrepreneurial [8]. Moreover, a raking classification of all startup ideas has been created by assigning a score.

A larger awareness about the importance of entrepreneurial learning has been raised. Faculty members have appraised and assessed entrepreneurship as a competence. Lately, Startup Garage Team has developed a digital assessment system to form up an “learning sheet” whose evaluation criteria rely very closely on “EntreComp three areas and 17 competences” as described and explained in European framework [8]. Entrepreneurial skills and attitudes can be monitored, recognized and assessed all along the non-formal learning process in the Startup Garage, following three steps (Figure 2). Effectively, once startup ideas are discovered and retained, successful applicants can work on them supported by Startup Garage Team management. During the first learning step, creative and visionary students identify real needs related to their ideas, so as to develop business opportunities. They explore solution to new challenges in a fast changing market. Once the potential of startup ideas is recognized, second step will lead students to check their ideas with limited resources provided. Proof-of-concepts are planned. Peers, teammates, active mentors are there to help them. Students are facing with cost budgeting in order to develop prototypes and marketing surveys. They team up with other students and let their ideas to be known by sectorial experts in individual and common meetings. If admitted, students will experiment a challenging third step, which is devoted to validate startup ideas by testing prototypes. Once self-confident, students draw up professional business plan. They are ready to present their startup ideas outside. They go into action. Eventually, students will show entrepreneurship as a competence for life, which help them certainly, both to find a job, and to set up a start-up business.

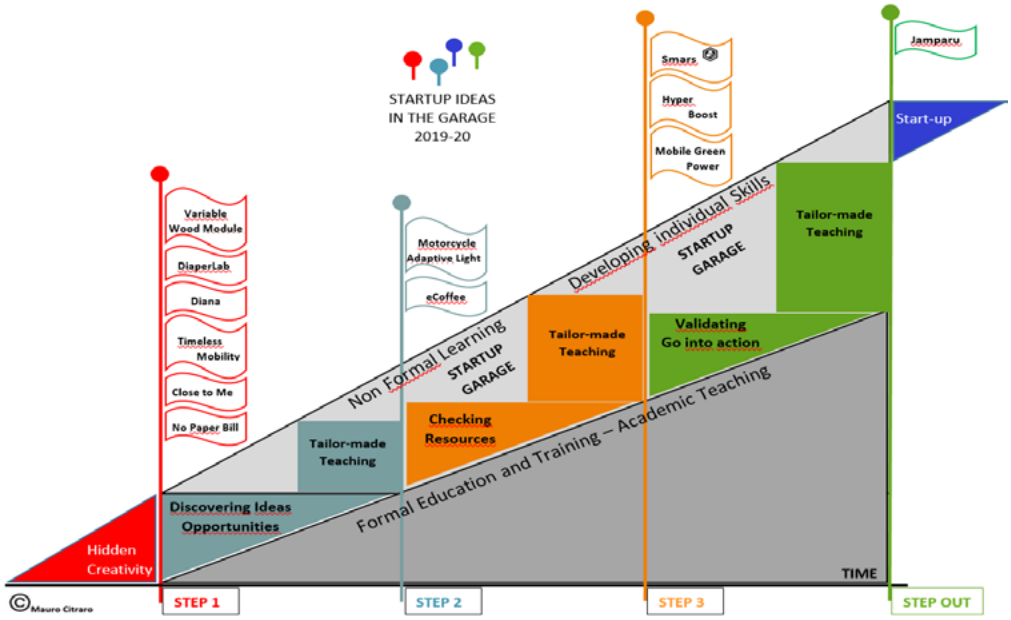

Fig. 2 – Apply EntreComp wheel in the non-formal Startup Garage learning process

3 STARTUP IDEAS AND THE MARKET

For pre-revenue businesses, as idea startups are, need a proven defined concept to build a strong position to demonstrate their future profitability and protect the intellectual property. If entrepreneurial students have a patentable idea, they may raise angel investment to formally

fulfill the patent application. The people involved in a business have been shown to be the most significant aspect for angel investors when deciding to make an investment, taking into consideration their experience, skills, drive, and the impression they make. They will then of course look carefully at the business itself and the core aspects of the business plan.

4 PINGEL@P

A digital platform is specifically developed to organize activities offered around the students with startup ideas (see "Leo Student Circle" in Fig.1). It continues to develop by taking into account changing needs from stakeholders and the increasing demand to protect IP. Pingel@p, assists with the collection and assessment of startup ideas and in particular matches entrepreneurial students with teacher stand-by mentors. An algorithm associates an idea with a potential to the most suited stand-by mentor, mainly on the basis of the needs expressed in the idea description, the competences declared by the stand-by mentors, and according to industry sectors. Three main parameters are required to be evaluated on an idea by a mentor: technological feasibility, innovation items, and business potential breakthrough.

After the assessment, a general ranking of startup ideas is produced. Every year, only a number of submitted ideas are retained and admitted as startup ideas in the Startup Garage (see Fig. 2). Once the assessment and admission process is ended, students will know their voluntary teacher at disposal as an active mentor. Thereafter, every step forward in developing startup ideas will be "certified" by a new "learning assessment", which "measures" entrepreneurial knowledge acquisition on the basis of relevant elements extrapolated from EntreComp framework. In order to satisfy increasing inputs coming from enterprises' partner, thanks to Pingel@p they will soon be profiled and classified in order to assign them with an active role to encourage entrepreneurship. As enterprises associated to Startup Garage they have right to "call for needs resolution" awaiting entrepreneurial students to help them.

4.1 IP and Blockchain

Recently "Startup Garage Concept" has been extended to contain a method to exploit blockchain for Intellectual Protection (IP). Since the first implementation of the repository, idea ownership has been safeguarded after their insertion by recording a timestamp of the first reading of the idea description by any user (e.g. stand-by mentor). An agreement is presented in a disclaimer stating the terms of use of the accessed content, establishing a sort of contract. Blockchain technology has been used in a lot of different context and applied also to protect intellectual property, such as for example in the Design Thinking process, where a unique hash is generated from each digital artifact and digitally stored into a blockchain network to guarantee both proof-of-existence and proof-of-origin [9].

Effectively, blockchain technology establishes ownership via a decentralized ledger that consists of a short description of the nature and goal of the invention according to the idea structure in Pingel@p, where a user would then have to accept the provisions of an agreement ("smart contract") to gain access to more information on the invention works. A further step towards a stronger intellectual property protection has been recently accomplished through

blockchain smart contracts. It is very hard to corrupt to system, and makes it easy to record the ownership of “smart contracts”. This mechanism is used here to protect ideas and it is implemented as a software module (in progress) integrated in the Pingel@p web application on the server side in Java. The rationale behind blockchain adoption for idea farming protection is supported by the fact that while companies usually have lawyers to defend their intellectual property, small inventors do not have many options to create an indelible record of their authorship.

5 NON FORMAL LEARNING

5.1 Concept

A new concept has been introduced into the Garage to apply knowledge in an intertwined and interconnected pattern of collaborative entrepreneurial education. The innovative idea puts together three different categories of participants: students, stand-by mentors, employees and managers. It will blend innovation and business spirit, thus reducing the gap between academics’ constraints and business’ needs. Students have great enthusiasm and creative spirit, but less organizational and business experience; stand-by mentors have high and specialized technical competence and a scientific approach, but low business experience; manager and employees have high performance and experience in business organization, but low access to top research. According to main requested skills, students may learn to be entrepreneur thanks to an education method managed to: encourage the cross fertilization of skills and competences; transmit entrepreneurial skills; motivate multidisciplinary teams; learning by doing implementing an idea in mixed groups during the training course. It comes out that a new course “tailored-made” has been introduced: *The enterprise of an Idea* (3 ECTS). It is addressed to students holding a startup idea, to stand-by mentors and employees and managers of enterprises. Every participant can choose topics his own interests and his startup idea’s state of development such as: inspiration and validity innovation, team work, product management, patent and legal aspects, accounting, financing, marketing and digital marketing, networking and pitch. In addition, Startup Garage team arranges almost every informal meeting (*Business Cakes*) in order to let students assess the feasibility of their startup ideas by critical peer-to-peer interactions. A multi-disciplinary way of thinking at their business.

6 PERFORMANCE EVOLUTION

An important indicator has been developed − Entrepreneurial Willingness Rate (EWR) − in a way to evaluate how many students out of a total of new students enrolled, show interest during the annual “call for ideas”. They have participated by applying through the ICT digital platform.

EWR has been specified in two different statistical indicators:

- EWR restrained (EWRre), by taking into account all students who have personally submitted an idea (applicants) out of total new students enrolled;
- EWR extended (EWRex) by considering the number of students (team mates) − who have joined teams built by succes [illegible] nts − out of total new students enrolled.

It results in the following statistical figures:

- Both EWRre and EWRex are quite impressive compared to a small reality and business environment: on average more than 10% of our students show over three years considered (2018, 2019, 2020) some entrepreneurial aptitude if scouted;
- Significant increase of the quality of the new startup ideas in terms of scientific and technical feasibility (number of retained ideas out of total submitted ideas);
- Applicants seem to prefer to submit new ideas individually and not, as previously, collectively; however, they have learned the importance of team work, because they are ready to enlarge teams during their stay in the Garage by exploiting the IT Pingel@p service "call for expertise" to find out students willing to help them;
- Significant percentage of voluntary teachers taking part as voluntary Stand-by Mentors: 25% on average of the total faculty members over three years considered.

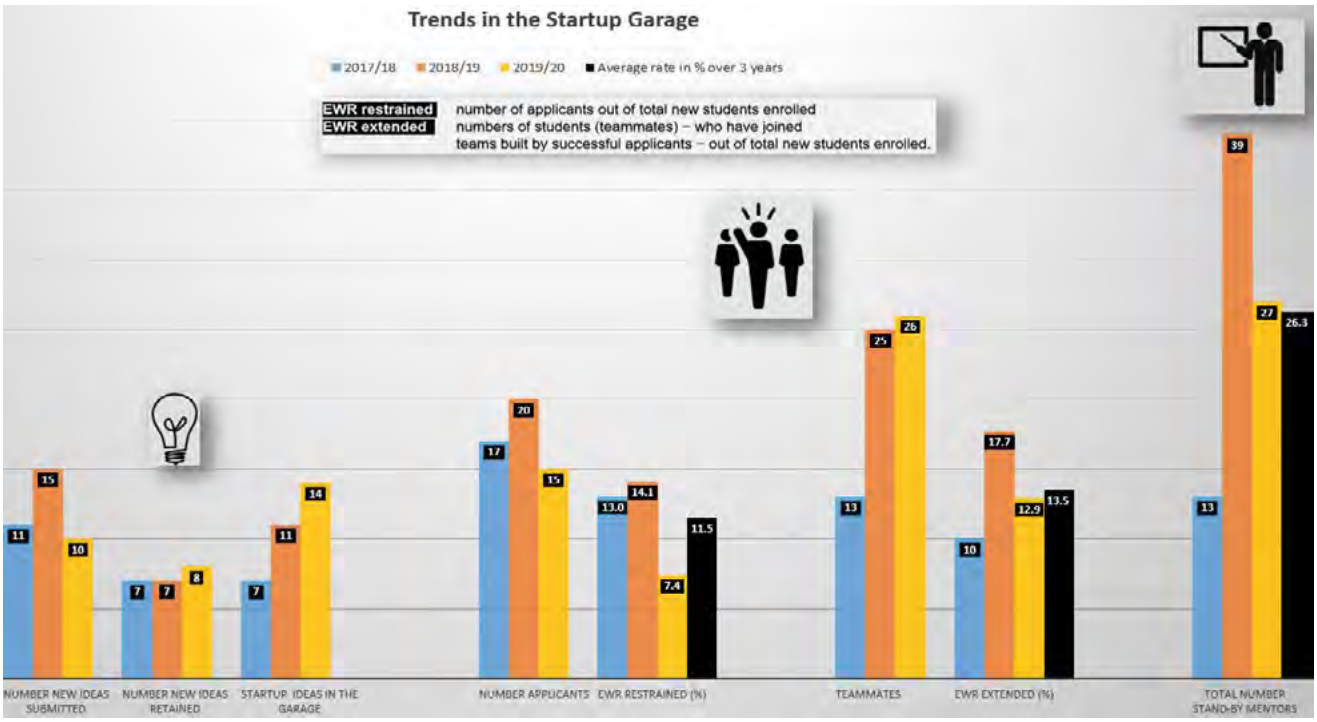

Fig. 3 – Trends in the Startup Garage

Emerging trends are surprisingly interesting, so persuading Startup Garage Team to keep managing all the process on a voluntary basis as done so far. It should be pursued with common and profitable perspectives for each stakeholder involved in spreading out the Startup Garage Concept and its realizing process.

1 CONCLUSIONS AND FUTURE WORKS

With Startup Garage, a step forward is made to empower the theoretical *quadruple helix* model. Starting from students, ideas flow across disciplines and stakeholders to become common values in a co-creation ecosystem. Combined with human competences and expertise, startup ideas are innovation inputs moving a dynamic process, an open system in which all stakeholders benefit because of common-purpose-driven actions.

As up-to-date consumer-driven subjects, students today are best fitted to create innovative products featuring new markets and services. Effectively, "Startup Garage Concept" leads entrepreneurial students to free up ideas from an internal state of mind, whose inputs are still, but ready to work if only stimulated. For this purpose, SMEs are soon going to act as a catalyst in asking students to implement/invent something new for them. An open window will be planned to let enterprises *"call for needs resolution"*. Students must be seen as an active subject, open-minded, potentially disruptive, different from a passive object, whose heads are there to be filled up.

Students can exploit classical theoretical-scientific instruments and knowledge, they gradually obtain during their curricula, into a stimulating practical adventure. In fact, students are encouraged to develop their own entrepreneurial ideas as an educational process, so interacting with both the academic knowledge and the business dynamics. In this process students receive objective feedbacks that can enable them to learn and evolve not only from their successful experiences, but also primarily from their own mistakes and failures

A quite large enterprise network will be soon integrated in the interaction system, in which SME, especially, should be much more involved within the Garage. At the same time, both start-up experts and professional advisors would be asked to guide students "out of the Garage" (Step out Guidance), if they want to set up a real start-up after having overcome steps in the Garage during their studies.

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EXPLORING QUALITY IN EU FUNDED ENGINEERING EDUCATION PROJECTS

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ABSTRACT

It is a requirement of Engineering Education Projects funded as part of the EU ERASMUS+ Programme to have a Quality Work Package as part of their project structure. On the surface this would appear an eminently sensible requirement, yet interpretations and implementation of this work package can often be confusing and challenging for project teams. Understanding what is required also links into the wider questions of what does Quality in Engineering Education really look like and how can the Quality Work Package help to drive the project thinking with respect to the sustainability and ongoing use of the project outcomes.

These issues will be explored within the context of a current ERASMUS+ Capacity Building Project called EXTEND. The project is seeking to develop the next generation of Engineering Educators in the Russian Federation and Tajikistan and is supported by partners from Romania, Latvia, Portugal and the UK. The coming together of 12 very different higher education institutions around a common goal has exposed how diverse a range of approaches to the subject of 'quality' there are when considering engineering education projects.

The paper will share the methodology adopted within this particular project and consider it with respect to the wider EU funded Engineering Education Project landscape.

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1 INTRODUCTION

Quality is a word that is common in the vocabulary of those of us engaged in engineering education. The question is - do we know what it means? When we refer to quality, are we clear about the context and are we consistent with what we mean? The contention of this paper is that when we refer to the quality of engineering education projects, such as those funded through the EU Erasmus+ Programme [1], we need a more robust understanding of what quality actually refers to and what it is seeking to achieve.

When engineering education projects receive funding to enable their execution, it is important that the project achieves its stated outcomes. This is generally ensured through sound project management so where does quality appear in this scenario? In Erasmus+ Projects there are generally two identified work packages, one for Project Management and one for Quality. How these work together and what the 'quality goals' are form the subject of this paper.

2 BACKGROUND LITERATURE

When we consider quality, the context is of considerable importance.

The Cambridge English Dictionary definition of quality is 'how good or bad something is' or 'a high standard' [2]. These are a helpful starting point but vague when we consider the engineering education contexts we work in. In order to explore this further, three different contexts will be considered and discussed. These are

- Quality in Engineering
- Quality in Projects
- Quality in Higher Education.

2.1 Quality in Engineering

As engineers, the idea of quality forms an integral part of our education and training. We are introduced to the idea of quality engineering and its foundation, the quality system, at a very early stage [3]. The work of Deming and colleagues is the foundation on which many ideas have been developed. The focus on the optimisation of product quality through effective design, manufacturing and checking processes with inbuilt feedback loops to enable the early detection and rectification of problems and the continuous improvement of the whole system is the fundamental objective. Over time, the development of numerous tools and techniques has allowed the system and the decisions it promotes to be based on clear evidence of performance in a numerical form. This builds confidence and enables continuous improvement to be driven from an informed position.

Quality Engineering has matured into an important discipline within the broader engineering context and has been extended beyond the initial 'product' focus to address 'service' industry scenarios as well. For example, designing and manufacturing a laptop produces a tangible 'product', whereas the repair of a laptop represents a 'service'. The ISO 9000 Standard along with methodologies like Six Sigma have resulted in a well-defined and robust discipline.

2.2 Quality in Projects

The project is a fundamental building block of industry today. Many engineers find that project management can form a significant component of their job responsibilities as their career progresses, so understanding what quality means in the project context is important.

The starting point for project quality is the Iron Triangle – the coming together of three key elements of a project [4]. These elements, the specification, the budget and the time available, need to be known and monitored throughout the lifetime of the project. The aim is to achieve the required tangible output within the identified financial budget and in the time period that is available. These ideas are the foundation of project management and are explained in all standard texts.

Over time the approaches to ensuring project quality i.e. the fulfilment of the stated needs in the Iron Triangle, have developed and today's project manager can apply different techniques to build confidence that a project will reach a successful outcome, an example being Earned Value Analysis. Similar to the ISO Standard for quality engineering, project management is guided by Bodies of Knowledge such as that produced by the UK Association for Project Management [5].

What we can notice in the two contexts discussed so far is that although initially the attempt is made to identify and use numerical evidence to demonstrate performance and support decision making, inevitably as we move to service quality and the adherence to specification elements, elements of subjectivity and less well defined measures of quality are introduced. In both cases though, the meaning of quality is firmly rooted in the idea that 'something meets a required need'.

If we consider the educational context, what we are presented with is a more complex scenario.

2.3 Quality in Higher Education

The Higher Education context is less able to rely on numerical data when assessing quality. Student and teacher experiences and perceptions are critical to understanding quality. These by their very nature are qualitative in nature and despite the numerous attempts to quantify them through end of course reviews and national surveys such as the National Student Survey in the UK, they need to be explored carefully in order to ensure the correct understanding is reached and decisions made.

We refer to quality as having two parts – Quality Assurance (QA) and Quality Enhancement (QE). Both are focused on the quality of student learning, which is the primary focus of any university [6]. Assurance is about ensuring the processes, infrastructure, content and personnel are in place to enable each and every student to realise their educational potential. In all parts of the world this is guided by agencies of Government that are tasked to demonstrate that identified standards are being met. For example the Quality Assurance Agency is that body in the UK. In assurance there is often a blend of quantitative and qualitative components, but the picture is more nuanced than say the delivery of a manufactured product [7].

Quality enhancement is the process of continuous improvement identified earlier. Decisions are made in this space based on QA data but also as a result of strategic imperatives, the need for change and the ambition of teaching teams and individuals. As can be imagined, this is not well defined, will vary from context to context and is often based on a variety of evidence. Having said that it is enhancement that has impact and adds value, yet too often it is a secondary consideration after assurance [8].

2.4 Synthesis and application to Erasmus+

It is based on a consideration of the three prior sections that we now consider how these characteristics are synthesised and applied to Erasmus+ projects. Erasmus+ projects are chosen as the focus for this work as, in recent years, this element of the European Union research funding has been the most supportive of projects in engineering education. Focused on the generation, dissemination and implementation of new ideas and practices that strengthen engineering education in the EU and beyond. Yet often these 'new approaches' don't have a marked impact across the community. Educators often come across ideas in an ad hoc way and the more far reaching impact is rarely felt. It is the contention of this work that part of the reason for this is that the Quality Framework applied within Erasmus+ projects, being left to project teams to define, lacks the focus and coherency to realise the impactful outcomes that justify the initial financial investment.

Considering the criteria used by reviewers of submitted Erasmus+ applications there is much scope for different interpretations of the nature of quality when applied to these projects [9]. This lack of clarity is then manifested in the variety of Quality Plans that are produced for the said projects. Taking two examples, the projects HARMONY [10] and EU-Mong [11], we see a range of commonly repeated features which suggest that the interpretation of quality is not consistent. In addition to the range of different terminologies used, the overlap between project management and quality and the reliance on numerical data, there is no focus on the lasting impact of the project outcomes, the ultimate measure of project quality.

2.5 Final thoughts

The brief exploration of the background topics that can influence the success or not of an engineering education project suggest that a more coherent and structured approach to the consideration of the Quality Work Package in projects would be of benefit. That way the return on the work conducted in terms of its impact across the European engineering education community would be enhanced.

3 APPROACH TO THE STUDY

This work is aimed at initiating a discussion within the European Engineering Education community around how we can work together to ensure a more effective translation of ideas and results from Erasmus+ projects to a broader cross-section of institutions such that the learning becomes embedded. The approach taken here has been to consider two case study examples that the authors have been participants in. The projects, their approach and the learning are explored to enable the articulation of an initial Project Quality Framework. This is very much viewed as a

starting point and that a broader exploration of past and current approaches is needed to better substantiate the draft Framework. This will form the next phase of the work.

4 CASE STUDIES

4.1 Case 1 – QAEMarketPlace4HEI (QAEMP)

This project (now completed) focused on ways to enhance the quality of engineering education by considering how QA and QE can work effectively together. The common theme was the partners' mutual interest in active learning, in particular the application of the CDIO (Conceive Design Implement Operate) framework [12] [13]. The partner universities were from Iceland, Finland, Denmark, Sweden, France and the UK.

When reading the detail of the Quality Work Package for QAEMP, the focus is primarily on the achievement of milestones, which, as has been stated before, is a project management task rather than a quality one. This allied to the need to prepare reports leaves little capacity to explore the real learning that is taking place and how this can then be translated into more widespread visibility and impact across the sector.

The lack of focus in the Quality space resulted in little 'continuous improvement' during the project implementation and consequently no significant lessons learned as a result of the journey each member experienced.

Although in terms of the ideas generated and the work conducted during the project lifetime, especially in the area of self-evaluation, the project was deemed a success, the extent to which the project has impacted the sector is minimal, even within the project partner institutions. With a more clearly defined and structured Quality Work Package the result could have been very different.

4.2 Case 2 – EXTEND

The EXTEND project (still in progress) is aimed at modernising the approaches used in teaching the engineering disciplines in Russia and Tajikistan. By increasing the quality of education through effective teacher education it is hoped to make engineering education more attractive, improve students' motivation and improve the possibilities of employment for young engineers [14]. The partner universities were from Russia, Tajikistan, Romania, Latvia, Portugal and the UK.

The EXTEND Quality Plan is constructed with 5 key points guiding. They are that it

- Is outcomes focused
- Works alongside Project Management
- Needs to be thorough but not overly bureaucratic
- Focuses on 'value of project activity' more so than compliance with the plan
- Is accepting of justified change.

In terms of the activity focus, three areas of work have been identified:

- A thorough review of each project meeting and the team operation
- Co-ordinating the setting up and operation of the External Quality Control Team
- Evaluating the quality and value of the project outputs.

Of these three areas of work, it is the latter that is considered the most important with two elements the focus:

- A review of the documentation produced to ascertain its value as a coherent and high quality record of the project as it was undertaken
- A review of the quality and value of the individual EXTEND Centres for Engineering Educator training.

In the case of this project, the Centres are the main output and it is their reach, impact and sustainability that will need to be evaluated to demonstrate success. A Rating Statement for each Centre that identifies areas of positive value and areas for development, alongside a description of the local context is a starting point.

One of the main challenges in these projects has been the overlap between work packages and the clarity in understanding where responsibility lies. Since projects adopt a work package approach with explicit responsibilities allocated in the form of work package leaders, there needs to be a clear and shared understanding as to how these will operate side by side. Often the Project Management, Quality and Dissemination work packages can have conflicting or overlapping tasks and the successful execution comes down to how well the team works together rather than due to having a robust framework in place. This was identified in the literature and experienced in both case study projects.

5 DISCUSSION

From both the background literature and the case study examples, it can be seen that the approach taken towards the Quality Work Package in Erasmus+ projects is variable. As a consequence the following ideas are offered as a starting point in the journey towards a more standard Project Quality Framework.

The initial proposal identifies three areas where the focus of the Quality work needs to be directed

- Quality of the Project Journey
- Quality of the Project Outcomes
- Quality of the Project Impact.

Explaining these in turn

a) Quality of the Project Journey

This would focus on the experience of the project participants. How valuable the various interactions are e.g. project meetings (face-to-face and online). The effectiveness of the project leadership. The important consideration here is not to get confused with the Project Management work package responsibilities. It is not about the achievement of deliverables but the effectiveness of the team in achieving the said deliverables.

b) Quality of the Project Outcomes

The focus here would be on what has been produced as a consequence of the project. This would consider the tangible outputs such as reports, papers and processes along with the quality and extent of the sharing of these outputs. The important consideration here is not to get confused with the Dissemination work package responsibilities. It is not simply about numbers but also the reach and the connections that are realised as a consequence of the work undertaken.

c) Quality of the Project Impact

To a large extent this would bring the previous two elements together and explore the ways in which the experience and outcomes are to be maximised in terms of the partner institutions and the wider engineering education community. This suggests that sustainability should be a part of the Quality thinking and that the project team should be required to demonstrate impact at an agreed point in time after the conclusion of the project work. This enhancement focused requirement would be an important step towards demonstrating the value of the funder investment in the project.

6 CONCLUSIONS

This paper presents some initial thoughts about how to better embed Quality thinking into Erasmus+ projects such that they are more able to demonstrate a wider impact beyond the project team. Through the implementation of a more structured and robust Project Framework with a requirement of the team beyond the stated duration of the project, the return on the project can be better demonstrated and a greater clarity of responsibility can be afforded during the project execution.

As a concept paper, this argument is presented in order to initiate a conversation. The next steps would be to explore more Erasmus+ Quality Work Package and project impact evidence and then to use this to further develop the Project Quality Framework proposal. On completing this work it would then be possible to share this with the EU Erasmus+ Team to explore whether or not it would be of value in guiding future Erasmus+ applications, the reviewing process and the impact of project outcomes. Many aspects of the Erasmus+ project application process are well defined, perhaps overly in some cases. This proposal attempts to promote a consideration of the importance of the Quality element and how this can be used to drive the greater impact of Erasmus+ engineering education projects.

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EMBEDDING A PROFESSIONAL IDENTITY FRAMEWORK INTO FACULTY WITH SEVERAL DISCIPLINES - A CASE STUDY

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ABSTRACT

Identity in engineering education has gained interest as a construct to improve academic attainment and retention, and to encourage students to graduate into engineering careers. Engineering identity is distinct and related to the constructs of motivation and self-efficacy. Many engineering faculty explicitly influence students' engineering identity development through skills inventories, and provide opportunities for enhanced skill development by reflective learning exercises. We report a case study describing how we introduced a novel professional identity framework into an engineering faculty which offers degree programmes across several disciplines. We describe its structure which comprises of four dimensions: Accreditation, Institution, Habits of Mind, and Career, with each dimension being characterised by a distinct skill inventory. We discuss our tactics for embedding this framework into an established setting, and explore some of its immediate benefits; monitoring skill progression across students years by self-ratings, measuring staff comprehension and engagement via the coding of their module descriptions, and measuring student understanding via the automatic natural language processing of student reflections on how their identity is progressing. Our framework and its embedding has the potential to encourage engineering faculty to think beyond accreditation requirements during programme development, improve module designs, and motivate students' skill development and career choice.

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1 INTRODUCTION

How can students' identification as engineers be explicitly encouraged and successfully embedded into engineering schools, and what is the benefit? The Cambridge dictionary defines identity as "who a person is, or the qualities of a person or group that make them different from others". Engineering identity is distinct to other constructs that yield similar benefits e.g. motivation and self-efficacy [1].
In education, whether students see themselves as engineers influences their academic performance and career choice [2]. Likewise, engineering schools' consideration of engineering engineering identity enables them to better understand their students, widen participation, and improve career destinations [3]. Our incentive is to better understand how to forge engineering identity in order to improve these outcomes, which contributes to solving STEM skills shortages that limit productivity growth in economies [4].
We present a case study for embedding a "Professional Identity Framework" into an engineering faculty which runs programmes for several disciplines at undergraduate and post-graduate level. It consists of a skill inventory grouped into a novel categorisation scheme of four "dimensions". We survey related literature on identity (section 2), outline the framework structure and some embedding activities (section 3), and evaluate its usefulness on a cohort of 513 students (section 4).

2 ENGINEERING IDENTITY

2.1 Definitions

Defining engineering identity and its progression has gained interest over the last decade. A recent systematic literature review of engineering identity [5] highlights several definitions and inconsistent relationships to the underlying social science. Common social science theories cited are Communities of Practice [6] and Cultural World Theory [7]. These theories emphasise environment and social norms as key factors for identity development. Many identity studies in STEM education define identity according to Carlone and Johnson's conceptual model [8] which comprises three overlapping aspects of identity: social, personal, and domain. Quantitative measures of student identity based on this model are realised through survey instruments e.g. [9]. Alternatively, student perceptions of their identity can be captured and developed through essay writing in engineering ethics modules e.g. [10].

2.2 Social, Personal and Domain Identities

The concept of social identity originates from Erikson's Self Identity Theory [11] [12] . The theory proposes that an individual identity is conceived through group membership e.g. the feeling of belonging to engineering faculty, the university, and to the engineering professional bodies. Multiple Identity Theory [13] proposes that your identity is continually reconstructed from four aspects: Nature i.e. biology; Institutional i.e. roles defined by institutions; Discursive i.e. how people interact with you; Affinity i.e. your feeling of belonging to groups.

Domain identity is dependent on a student's perceived performance, recognition, interest and competence in their subject [14]. The engineering domain may be considered to have constituents from its foundational subjects of maths, physics and science. Analysis of the 2011 Sustainability and Gender in Engineering (SaGE) survey of 6772 US college students revealed that engineering students have stronger physics and science identities compared to maths identities, and differ from science students in having more global agency [15].

3 PROFESSIONAL IDENTITY FRAMEWORK

3.1 Structure

Building on Carlone and Johnson's model for student identity comprising personal, social and domain identities [8], we embed it into faculty (*Fig. 1)*. The Engineer aspect of student identity (left plane expanded in the middle plane) is characterised by the student's subject interest, recognition, ability and performance [14]. The embedding framework (right plane) comprises of four dimensions:

A. Accreditation: The learning outcomes of an accredited degree.
B. Institutional: General skills and competences desired by the University for all students.
C. Habits of Mind: Thinking patterns associated with engineering professionals.
D. Career: Consideration of future identity and career.

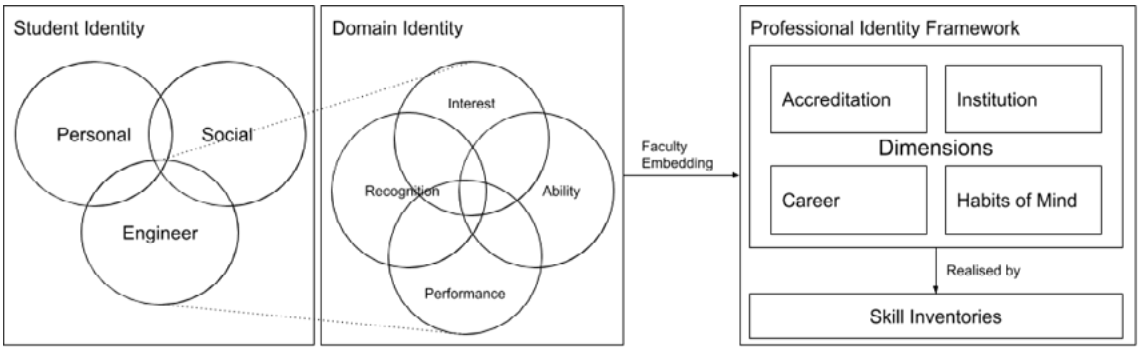

Figure 1 Professional Identity Framework for Engineering Identity

Each dimension has an underlying skills inventory. For Dimension A, Accreditation, these are learning outcomes for science and mathematics; Engineering analysis; Design; Economic, legal, social and environmental context; Engineering practice; Additional "transferable" general skills. Dimension B, Institution, covers the general and professional skills not fully defined by engineering accreditation as noted in [16]. Typically these skills reflect the local university priorities. Common skills for the Institution dimension include research-informed instruction [17] and developing Enterprise skills e.g. using the learning outcomes specified by the EU EntreComp Framework [18] [19]. Dimension C, Habits of Mind, concerns thinking patterns or competencies; automatic behaviours cultivated through constant repetition and reward throughout study. These describe how students approach complex challenges and are distinct from professional skills of Dimension B. We adopt the Royal Academy of Engineering (RAE) "Engineering Habits of Mind" model [4] formulated from extensive work with industry and higher education stakeholders. It defines six habits: systems

thinking, problem-finding, improving, creative problem solving and adaptability. Dimension D, Career, concerns students exploring their future identities for their skills for sectors and roles of interest. Building on work in [20], these recognise the different degree tracks and module choices through programmes tailored to their career aspirations e.g. Engineering Science for PhD, Engineering Design for Industry, Engineering Management for engineering consultancy, Policy/Society for government roles.

3.2 Embedding

To embed the framework into faculty, we develop a strategy following activities outlined in the "Five Dimensions of Growth" proposed by Costa and Kallick who pioneered Habits of Mind in pre-university education [21]. Some examples of stages relating to activities reported in section 4 are:

- Exploring Meanings:
    - Student exercises to build analogies to their own experiences around skills in the inventory including self-rating themselves against the skills (section 4.1) and reflecting on their coursework (section 4.3).
    - Academic teaching staff exercises to reword and rephrase skill descriptors to encourage adoption, plus training on aligning mapping their own teaching to the framework (section 4.2)

Other Stages and their Activities which maybe of interest to the reader but not further reported in this paper include:

- Increasing Alertness:
    - Environmental cues are introduced in the virtual and physical learning spaces. These include infographics videos and posters designed to activate engagement.
- Value Extending:
    - Existing reward and recognition systems incorporate the framework.

4 EVALUATION

We explore evidence to support the framework to answer the main research question posed in the introduction: How can students' identification as engineers be explicitly encouraged and successfully embedded into engineering schools, and what is the benefit? Three aspects are explored:

1) Student self-rating of skills: How do students rate themselves against the PIFs four dimensions? This enables the comparison between cohorts at different levels to characterise progression from non-engineer to engineer.
2) Staff engagement and comprehension: How do educators relate the PIF to their teaching? This enables us to identify how educators understand the PIF and which elements are favoured.
3) Student reflection on identity progression: How does the PIF help students progress their engineering identities? This allows better formulation of how each element is described through automatic analysis of student's language use.

4.1 Student self-rating of skills

As part of their yearly academic reviews, students from all undergraduate cohorts (*n=513*) were asked to rate themselves against each skill in each dimension using a five-point likert scale. The summary results (*Fig 2.*) reveal that, on average, first year Undergraduate students (UG1) rate themselves as differently than those in future years (UG2+). For Dimension A, the older cohort rated themselves as more skilled in Engineering design and analysis, yet less skilled in science and mathematics. For Dimension B (Institution) and C (Habits of Mind), the non-uniform differences for each skill between years potentially reveals the institution's programmes relative strength and weakness, but notably, older year groups are more conservative in estimating their skill levels. This could be demonstrating the Dunning-Kruger effect [22], a cognitive bias where low ability people overestimate their ability. For Dimension D (Career), results suggest that as students progress, they became more attracted to research and managerial roles, reflecting the emphasis on research-led teaching and encouraging student leadership skills to differentiate itself with others.

Fig. 2 Student self-rating of skills against each dimension's skill inventory

4.2 Staff engagement and comprehension

To measure staff engagement and comprehension, staff are asked to redraft their module descriptions and relate them to the framework. Redrafted descriptions are binary coded in 3 axes: whether they identify the relevant skills, whether they identify the relevant dimensions, and whether they contextualise the identified skills and dimensions in terms of the module content. 24 module descriptions are coded. An example of a redrafted module description which contextualises the framework for the module content would be: *"Dimension A: The module applies science and maths*

to give the understanding of the behaviour of fluids and energy, which underpins engineering design.". In contrast, an example where the framework is not contextualised to module content would be *"Dimension A: science, maths and engineering design".*

Coding revealed that 18 of the 24 responses directly refer to the Dimensions in the framework. 12 of these 18 also contextualise the identified skills or dimensions. Of these 12, 8 do it with respect to both skills and dimensions, whereas 3 do it with respect to dimensions only rather than the skills. For the remaining 12 that didn't contextualise the identified skills or dimensions, 5 listed only the skills. The remaining 7 who didn't contextualise listed the skills and dimensions together without distinction. The results suggest that staff find it easier to relate their modules to engineering identity when considering the four dimensions in addition to, or instead of, detailed skills inventories.

4.3 Student reflections on identity progression

Students (*n=513*) from all year groups are asked to reflect on a favourite item of coursework in terms of how they think it progresses their engineering identity for each dimension. *Table 1* gives an example of a student reflection and the number of responses for each dimension. In total, 2029 responses were analysed. Dimension A, Accreditation, attracts the largest number of responses, closely followed by Dimension C, Habits of mind. This suggests that students find it easy to relate their work to these two dimensions most strongly aligned to Engineering. Conversely, Dimension B, Institution, was the weakest attracting 10% fewer reflections. This could suggest that students find professional skills more difficult to reflect upon against specific pieces of learning, and/or the comprehension of local-generated skill inventories are inferior to those from national and global bodies. Dimension D, Careers, is also less reflected upon suggesting that not all students are career planning or see its relevance to coursework.

Table 1 Student reflections on identity progression

PIF Dimension	Number of Responses	Representative example of a student's reflective commentary.
Dimension A: Accreditation	526	*"This work has enabled me to apply my engineering analysis skills and also relate my chosen topic into a wider world context, something which I have only done in a limited way before"*
Dimension B: Institution	481	*"Research informed - I have explored my chosen topic in greater depth in writing this report."*
Dimension C: Habits of Mind	520	*"Problem Finding - Clarifying needs, checking existing solutions, investigating contexts, verifying."*
Dimension D: Career	502	*"Discovering new knowledge, collecting and analysing data and using digital data technologies."*

We compare vocabulary usage in the responses to determine whether there are differences between dimensions. 2724 distinct words are identified from the

responses. They are processed using established Automatic Natural Language Processing (NLP) techniques [23] in the following sequential steps:

1) Responses are corrected by hand for spelling and grammatical errors.
2) The sentence text is tokenised into individual words for analysis.
3) The text is shortened using stop word removal to eliminate common every day words such as “a”, “it”, “and”, etc.
4) Morphological variation in word use is reduced using Stemming and Lemmatization.

The algorithms were used the NLTK toolkit in Python 3 [24]. An example of processed text against each step is shown in *Table 2*.

Table 2 Natural Language Processing of Student reflections

Step	Example Processed Text
Original text	i demonstrated my research skills using the harvard referencing format
Original text after Stop-word removal.	demonstrated research skills using harvard referencing format
Stop-word text after Stemming.	demonstr research skill use harvard referenc format
Stop-word text after Lemmatization.	demonstrated research skill using harvard referencing format

Once the text is processed and morphological variation reduced throught stemming of lemmatization, individual word counts for each response were tallied for each dimension and compared. *Fig. 3* shows the results for lemmatized text.

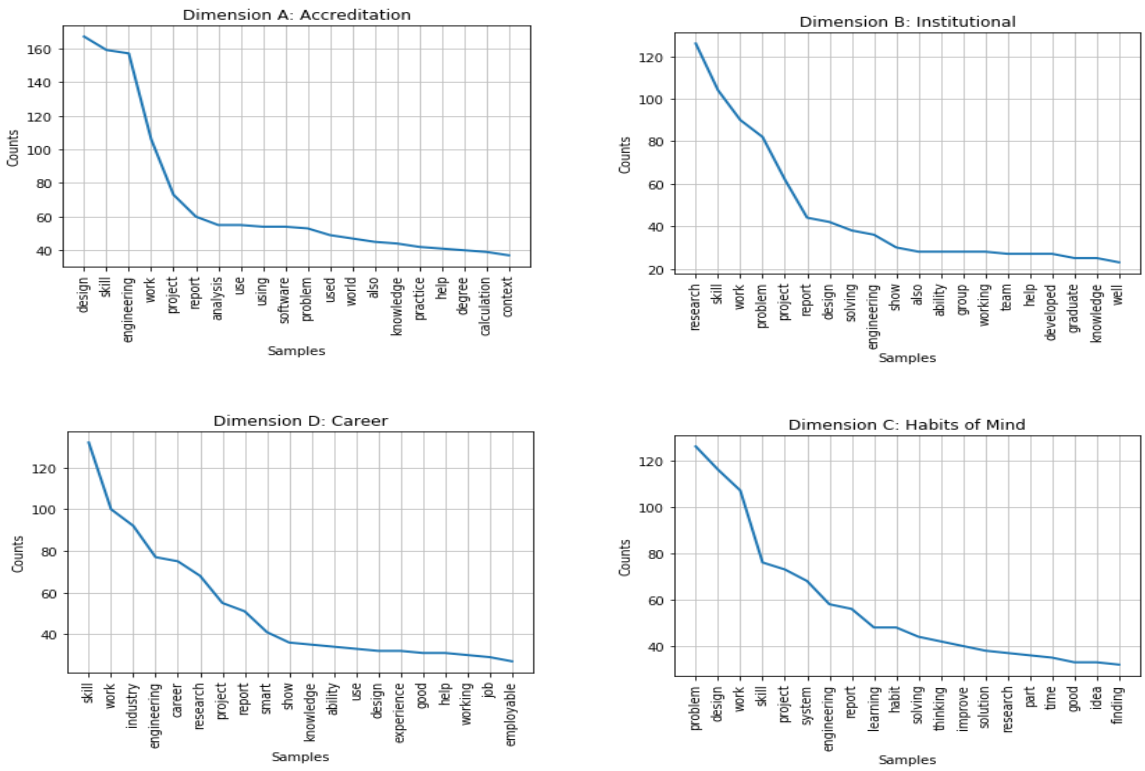

Fig. 3 Top 20 Word Count Distributions for each Dimension using Lemmatized text

Notably, each dimension's most popular word is different. Accreditation: "design"; Institution: "research"; Habits of Mind: "problem"; Career: "skill". Other words' relative popularities helps to determine whether the framework and distinctions between dimensions are comprehended by the student body. Word counts for stemmed and stop-word responses achieve similar results to the lemmatized responses.
To further understand the differences in vocabulary use between dimensions, the term frequency – inverse document frequency (tf-idf) is computed for each word. This measure calculates how important the term (word), *t,* is in a specific document, *d*, given a collection of N_D documents i.e. the corpus:

$$tf_idf(t,d) = tf(t,d) * \log(\frac{N_D}{df(t)+1}) \quad (1).$$

Where *tf(t,d)* is the term frequency – which is computed from the count *t* in the document in proportion to the overall count of *t* in the corpus:

$$tf(t,d) = N_{t,d}/N_t \quad (2).$$

And *df(t)* is the document frequency – the proportion of documents in which the term occurs:

$$df(t) = N_{d,t}/N_D \quad (3).$$

In this context, terms are individual words, the document represents all text in the responses for a specific dimension, and the corpus is all dimensions. The results of computing the tf-idf for words having the highest scores are shown in *Table 3*. Each row highlights the highest scoring dimension for that word. Notably, the top four words correspond to different dimensions.

Table 3: tf-idf scores for words used by students

	Dimension			
Word	**Accreditation**	**Institution**	**Habits of Mind**	**Career**
research	0.07	**0.43**	0.10	0.22
skill	0.38	0.35	0.21	**0.41**
design	**0.40**	0.14	0.32	0.10
problem	0.13	0.29	**0.37**	0.09
engineering	**0.37**	0.12	0.16	0.24
work	0.25	0.30	0.30	**0.31**
industry	0.04	0.03	0.02	**0.29**
career	0.01	0.00	0.01	**0.23**
project	0.17	**0.21**	0.20	0.17
smart	0.00	0.00	0.00	**0.19**

5 SUMMARY

We proposed an professional identity framework for engineering students. Our evaluation shows that it provides a means to measure skill progression, and validates the distinction and usefulness of grouping skills under the four dimensions of Accreditation, Institution, Habits of Mind, and Career. This framework can be used to broaden programme development beyond meeting accreditation requirements, provide educators with perspectives to reframe teaching to consider identity formation, and help students motivate their studies and career choices.

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TOWARDS CERTIFIED LEARNING ASSISTANTS FOR IMPROVING EDUCATIONAL QUALITY

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ABSTRACT

Undergraduate students can be appointed as 'student assistant' and as such they can fulfil many different tasks, related to education, research and organisation. These tasks vary from entering data or making schedules to guiding tutorials or assisting in lab settings. In the year 2018/2019 at the University of Twente, an estimated 51.000 to 84.000 student assistant working hours were spent on learning-related tasks. In order to enhance the quality of education at the university, it is proposed to extend the didactical training for student assistants with tasks in which they are formally involved in other students' learning processes (Learning Assistants, LAs).

The Learning Assistants Project at the University of Boulder, Colorado [1] has been an inspiration. By incorporating elements of other LA trajectories, the 'Colorado LA Model' has been adapted to the local situation and demands. The main goals of the intervention are that Certified LAs show a reflective, professional attitude aimed at improving their practice as LA and that LAs can determine pedagogical strategies for assisting, when provided the goals, teaching strategies and assessment of the unit they are asked to assist in.

Following a rapid prototyping approach [5] an LA-training trajectory is designed and implemented at small scale. Simultaneously, an inventory is being made of the current roles and tasks of LAs, and more in-depth needs analysis for the design of this training. This article present the first results of both the training needs assessment and the pilot LA-training.

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1. INTRODUCTION

In The Netherlands, undergraduate students can be appointed as so-called 'student assistant', and as such they can fulfil many different tasks, related to education, research and organisation. These tasks vary from entering data and making schedules, to guiding tutorials or assisting in lab settings. In the year 2018/2019, at the University of Twente, an estimated 51.000 to 84.000 student assistant working hours were spent on tasks in which the students were formally involved in other students' learning processes – from now on called 'Learning Assistants' (LAs). The LAs are prepared on the content of their work by the lecturer who hires them. Part of the LAs also get a pedagogical preparation, which is provided by the University's Centre of Expertise in Learning and Teaching (CELT), consisting of a half-day session at the start and a follow-up lunch meeting during the quartile.

In general, in evaluations, students are satisfied about the content expertise of the LAs, however, the opinion about the didactical skills vary from good to unsatisfactory. Student representatives in departmental and university bodies have asked for more extensive didactical training for LAs. The Learning Assistance Model of the University of Colorado [1] was mentioned as a good example of what they would like to see at the UT.

The Centre for Engineering Education (CEE) has taken up this idea and has worked on implementation of the plan in cooperation with the Department for Teacher development (ELAN) and CELT. This has led to three main questions:

1. What should be the content of the more extensive didactical training; what skills are most relevant?
2. What is the best format, considering the busy schedules the LAs already have? And should the pedagogical training be offered at university level or per department or program?
3. How can this more extended training be implemented, who will train, is extra staff needed, etc.?

To answer the first two questions it was decided to do a training needs assessment (TNA, see section 2.1) and at the same time, after study of several existing LA-training trajectories (section 2.2), to do a pilot of a possible LA trajectory to gain experience with the content, format and study load (section 2.3). Based on the outcomes of the TNA and the pilot, the third question can be answered later.

2. METHODOLOGY

2.1 Training needs Analysis

Information has been collected on the:

- current situation: number of LAs and LA hours per program, LA recruitment, LA tasks, current LA training
- training needs: How do LAs perform? What goes well, what needs improvement? What additional training is needed?
- conditions for a pedagogical training for LAs: How to 'pay' for the time investment? Maximum study load? Will trajectory be compulsory? Will certified LAs be paid extra?

The information has been identified by means of interviews with management and teaching staff from various faculties and programs, students who have fulfilled LA tasks (with various preparation), and students from the 'consumer' perspective.

2.2 Relevant examples

2.2.1 University of Colorado – Learning Assistance community

The 'Colorado LA model' is taken as starting point. This university has ample experience with the use of learning assistants. These assistants, undergraduate students, are used to optimize student guidance as well as transformation of courses into more interactive and engaging learning environments.

Learning Assistants engage in three main weekly activities as part of the LA Model: Content preparation meeting (Plan with faculty), Pedagogy course (learn and reflect on effective pedagogy), and Practice (work with and support students in the classroom). Whereas the weekly content preparation meetings are organised per course, the pedagogy course provides a community for new and experienced LAs from different courses and departments.

Research on the effects of the model [2] has shown that the quality of education improves. Results indicate improved student performance and a clear decrease in failure rates in the classes that included LAs. The model of learning assistants has been copied by many other institutes for higher education, and has led to a worldwide LA Alliance.

2.2.2 Other LA-training programs

For adaptation of the model to our local situation and demands, several other examples of LA-training have been studied. The way the Norwegian University of Science and Technology (NTNU) [3] (and other Nordic universities, collaborating in the 'Experts in Teamwork' network [4]) uses LAs to teach teamwork skills is interesting for us to prepare our LAs for possible tasks as supervisor of lab groups or tutor of project groups.

Two methods used in LA-training at the University of Utrecht seem to be useful for out training as well: the 'action plan' shows LAs how they can develop their skills further and the 'constructive alignment exercise' makes the LAs aware of the set-up of a whole course, how their component fits in and how the course could be optimized. It makes LAs more equal discussion partners for the lecturers.

At our own institution, two examples for preparation of LAs are studied. First, the current course as offered by CELT: a half-day session with basic information and some practical exercises, and an intervision meeting halfway the quartile. Another example is the approach by the Technical Medicine program. LAs are hired for a whole academic year as student-tutor of project groups for several courses in a row, while guidance is given by two-weekly intervision meetings at lunch time.

2.3 Intervention design

Conform the Colorado LA model, a pedagogical component is added to the already existing regular content preparation meetings with the lecturer and the work as LA. Following a rapid prototyping approach[4] an LA-pedagogical training trajectory was designed and is currently being implemented at small scale. The major goals for the intervention are to prepare LAs in such a way that (1) LAs make the shift from learner to teacher perspective and role, (2) LAs can determine strategies for assisting, when provided the goals, teaching strategies and assessment of the unit they are asked to assist in, the course, module and program as a whole, and (3) LAs show a reflective, professional attitude aimed at improving their practice as LA.

The design was discussed with a group of experienced LAs and 'consuming' students to get feedback. This has resulted in reduction of the study load from 2 EC

(56 hours) to 1 EC (28 hours). Both LAs and students said that a 2 EC-trajectory would not be feasible next to their own studies and work as LA.

The designed LA trajectory consists of a three-hour kick-off meeting before the first quartile in which the LAs assist, followed by eight one-hour lunch meetings spread over two quartiles, six in the first quartile and two in the second one. The two quartiles are not necessarily adjacent; the second quartile is the next quartile in which the LA assist again. The second part is relatively short and focusses on the transfer from what was learnt in the first part to the new LA tasks.
Each lunch meeting consists of a combination of intervision (discussion based on LAs experiences), new input (theory and application of this theory) and homework. LAs reflect on their practice, develop a plan for improvement, and evaluate this plan. At the end of the intervention the LAs are asked to reflect on their learning and on the process of the intervention.
The program of the meetings is described in the following scheme.

Scheme 1: Program of pilot LA-training

Meeting	**Program**	**Homework**
part 1 in Q1:		
Kick-off meeting	What is learning?	Discuss your role and tasks with lecturer
	Role LA	
	Building relationships	
	Questioning and answering	
	Prepare first session with students	
Lunch meeting 1	Intervision	Read article SPA Make SPA for student tasks and for your LA work
	Systematic problem approach/SPA	
Lunch meeting 2	Intervision	Read article groups processes and interventions
	Group processes and interventions	
Lunch meeting 3	Intervision	Make action plan
	Feedback and formative assessment	
	Start action plan	
Lunch meeting 4	Intervision	Redesign component of course in which you assist
	Constructive alignment	
Lunch meeting 5	Intervision	Write reflection report (reflect on your development as LA, make action plan for next time that you assist and evaluate part 1 of the LA course)
	Presentation of action plan	
	Presentation of redesign	
Lunch meeting 6	Intervision	
	Discussion of reflection reports	
	Looking forward to part 2 of LA course	
part 2 in Q2:		
Lunch meeting 1	Link Reflection report to your new LA tasks	Transfer what you have learnt in part 1 to didactical strategies for new LA tasks Make action plan
	Define new research question for action plan	
Lunch meeting 2	Discussion of results	
	Intervision	
	Rounding off and award of certificates	

2.3 Participants

Six students participate in the pilot intervention. They all were hired in the first quartile for tutor-tasks: guiding group processes in small groups of students. Furthermore, one LA was also involved in guiding students during lab sessions. All but one did not have prior experience in supervising or guiding group work. All

students have followed the course they assisted in as a student themselves (1-3 years ago). In the second quartile they will get other LA tasks.

3. RESULTS

3.1 Training Needs

The TNA has not yet been finished. Preliminary results show that the chosen focus on three LA tasks in the pilot seems to be well chosen: assisting in working groups, assisting in lab sessions, and facilitating the development of individual skills and teamwork skills in project groups. The topics mentioned by the interviewees are in line with the topics of the pilot, only summative assessment is mentioned by several interviewees but is not included in the pilot.

The current preparation of LAs for their tasks varies enormously, not only between faculties but also between programs within faculties. Perspectives on the relevance of this preparation (within programs) differ between teachers and LAs. In general, all stakeholders see the relevance of LA preparation. However, especially based on current LA perspectives, the preparation of faculty staff for making good use of LAs could also be an important element of such an intervention.

3.2 Intervention Evaluation

The first part of the trajectory has just been finished, the (shorter) second part is still to be given. In general, LAs are very positive about part 1 of the intervention. They value all topics that were offered and have not missed topics. Especially the topic about group processes and interventions, and the combination of intervision and a new topic are highly valued. They see the action plan methodology as a good way to improve their way of assisting further and the constructive alignment assignment has helped them to see the larger picture of the quartile and how the component they assist in fits in the picture.

The duration of the trajectory,1 EC, is good. However, sessions lasted only 60 minutes, which was perceived as short or sometimes rushed. LAs indicate they would have valued more extensive discussions and opportunities to ask more questions. They advise to offer different time slots for the course, at lunch time but also at the end of the day and on regular afternoons (when several LA trajectories will run in parallel in the future, this will be feasible). During this pilot all LAs assisted in the same program and performed the same type of tasks. Three LAs explicitly mentioned they would have preferred a more varied group of LAs in the trajectory.

In general, LAs indicate that they have reached the goals of the programme. They all say they have made the shift from learner to teacher perspective, they have gained confidence in their role as LA and they expect that they are able to prepare themselves for the pedagogical approach of new LA tasks. They have gained in-depth knowledge and insights into their role with regard to the *learning* of the students they guide or supervise. For example with regard to learning objectives, one of the LAs writes: "*Before these sessions I always assumed that if I passed the courses I would end up with enough skills to get to work. I thought the goal of the classes was to gain more knowledge. Now I think more actively what the goal is of a certain class. (…) It made me realize that a good process is important to get a good result and that a good process is a goal itself.*"

The lecturers and project coordinator could not yet say much about the results of the trajectory and the performance of the LAs. They wait for the outcome of exams, the project reports, and the formal course evaluation by the students.

3.3 Lessons learnt

Although we have not finished the TNA and the pilot we can already draw some preliminary conclusions.

There seems to be sufficient support from all stakeholders at the UT for more extended training of LAs.

We seem to be on the right track with the format and study load of the TA-training. The Colorado model, that offers the content preparation by the lecturer and the pedagogical training in mixed groups in parallel to working as LA, works well. Spreading the course over a longer period is useful, LAs need intervision and new input to gradually grow and become confident. A study load of 1 EC seems to be feasible and sufficient to reach the objectives of the pedagogical training.

Also the objectives and content of the LA-training seem to be well chosen. Objectives and topics are in line with the preliminary findings of the TNA. It might be necessary to add a topic on intercultural aspects. Since we had two international LAs in the pilot it got sufficient attention in the pilot; in purely Dutch groups this might be different. We might also decide to add summative assessment as a topic (although we are of the opinion that students should not be involved in summative assessment of other students), since many LAs are involved in it. Further finetuning and development of all topics is needed. A good article per topic that provides concise and easily accessible extra info needs to be selected.

More communication between trainers and teaching staff is advisable. The use of LAs in courses can be optimized and some finetuning about the role and tasks of LAs in the courses, especially on the tutor role, is needed. Differences in opinion among teaching staff and between teaching staff and trainers were observed. We expect that certified LAs will start these discussions in the future but for now we will have to do this.

The Colorado LA model has more objectives than just improvement of the guidance given to students: one is the transformation of courses into more interactive and engaging learning environments and another is to motivate students to become K-12 teachers. Although course transformation is not a goal at the UT, we expect that, based on the competences the LAs have gained in the pilot, LAs can indeed play a role in re-design of courses and quality improvement. Also motivating LAs for a career in teaching can become a welcomed outcome of the LA model at the UT, there is a shortage of science teachers in the Netherlands.

An important element of the Colorado model is the community of LAs. Although the UT is still far away of a community, we see that this could become feasible in the future, when many more LAs are trained: A community for and run by certified LAs that meets once or twice per quartile and offers exchange of experiences and new or advanced topics.

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INNOVATION WITHOUT CREATIVITY? – TEACHING CREATIVE PROBLEM SOLVING TO PROSPECTIVE ENGINEERS

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ABSTRACT

Engineering can be understood as a sub-category of creative problem solving with a focus on functionality. Engineers are often expected to come up with and implement new and better solutions in a company. The aim of this paper is twofold. Firstly, it gives an overview of the status quo of how creative problem solving is taught at German tertiary institutions (universities and universities of applied sciences). As a result, only a weak reflexive examination of creativity could be detected and only sparse teaching of creativity techniques seems to take place. Secondly, the paper discusses first experiences of teaching creative problem solving in engineering and presents some tentative results on preferences and effectiveness of creativity techniques. The results are derived from a master course with a practical part in which student had to redesign an everyday object using amongst others a range of creativity techniques.

1 INTRODUCTION

1.1 Creativity in Engineering

Creativity is typically defined by the two components of originality and effectiveness [1]. Originality refers to novel attributes of a creative product, while effectiveness signifies the usefulness, appropriateness or value of a creative solution. Creativity plays an important role in engineering, as engineers are often faced with situations in which they need to seek novel solutions for engineering problems.

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This does not only include solutions in innovation management and new product development, but also more mundane aspects of day-to-day work such as, amongst others, production process improvement, logistical challenges as well as repair and maintenance of equipment.

Engineering can even be understood as a special way of creative problem solving. For the field of engineering, Cropley & Cropley [2] suggest the term “functional creativity” to describe the creativity necessary for industrial products such as engineered items or manufactured consumer goods. Functional creativity differs from e.g. expressive creativity of artists by its focus on the useful purpose of novel products. A novel product of engineering must fulfil its intended need and adequately solve an addressed problem. Thus, functionality as part of the effectiveness side of creativity is more important than originality for engineering. Creativity in engineering can be taught by explaining fundamental strategies of creative problem solving and by instructing students in the execution of creativity techniques.

1.2 Creativity Techniques

Creativity techniques are methods or tools which include a set of rules of behaviour and thinking in support of idea generation. They are ususally based on idea-generating heuristic principles of association, combination, confrontation and imagination [3]. A major classification of creativity techniques concerns the procedure and distinguishes between intuitive and discursive techniques. While intuitive techniques activate the subconscious mind to spontaneously generate ideas, discursive techniques take a systematic-analytic approach to idea generation [4]. Another major way of classification is into the two principles of creativity by de Bono [5] – or lateral thinking as he calls it – which are generation of alternatives and challenging assumptions. Generation of alternatives includes the idea-generating principles of association and combination, and challenging assumptions contains confrontation and imagination. Fig. 1 shows examples of established creativity techniques according to these classifications.[2]

Another way to create ideas – especially in invention and product development – is the use of creative heuristics. A creative heuristic can be defined as “a strategy or rule of thumb for generating ideas or for solving problems” [7]. Typical heuristics are the SCAMPER[3] checklist and the heuristic principles of the theory of inventive problem solving (TIPS/TRIZ).

[2] Descriptions of established creativity techniques can be found e.g. in [3], [4] and [6].
[3] Acronym for the heuristics: Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse.

	intuitive	discursive	heuristic
Generation of alternatives	Brainstorming Brainwriting 6-3-5 Method Mindmapping	Morphological box	SCAMPER
Challenging assumptions	Reversal method/ Anti-solution Forced connection	Theory of inventive problem solving (TIPS/TRIZ)	Heuristic principles of TIPS/TRIZ

Fig. 1. Established Creativity Techniques and Heuristics

This paper pursues two research questions: Firstly, it examines the status quo of how creativity is taught in German tertiary institutions by assessing course catalogs. Second, it examines experiences in teaching creativity techniques to prospective engineers in a German master course by assessing the use of creativity techniques by the students.

2 METHODOLOGY

2.1 Assessment of Course Catalogs

The focus of the assessment of course catalogs is on the content of module descriptions of bachelor study programmes in mechanical and process engineering. For the assessment, the course catalogs of the ten largest German universities and the nine largest German universities of applied sciences (plus the university of applied sciences of the authors) in this field were selected. As a criterium for the size of the tertiary institutions the number of students was chosen according to the online prospectus of German universities Studis-online (www.studis-online.de) which is based on data coming directly from the tertiary institutions as well as from the German Federal Agency of statistical data (Statistisches Bundesamt). The analysis did not include private universities and distance universities.

The analysed course catalogs contain in total 818 modules of universities and 649 modules of universities of applied sciences. The content of the module descriptions was analysed with regard to the teaching of creativity. Therefore the mention of key words was checked in the following categories:

- Category 1: Mention of the words “creativity” (in German: “Kreativität”) or “creative” (in German: “kreativ”) in the title of the module
- Category 2: Mention of the words “creativity” or “creative” somewhere else in the module description
- Category 3: Mention of synonymes for “creative” in the module description[4]
- Category 4: Mention of established creativity techniques in the module description[5]

2.2 Assessment of Creativity Techniques

For the assessment of creativity techniques, a master course in industrial engineering at the Düsseldorf University of Applied Sciences (HSD) was analysed. The course took place in the summer semester of 2018 (SS2018). During the course, the prospective engineers worked the entire semester of 14 sessions in goups of five on a self-chosen problem to redesign an everyday object ending with the students presenting their solutions. Participants were students with bachelor degrees in engineering, partly from HSD, partly from other German tertiary institutions. In total, there were 40 students in eight groups. The students were trained during two lectures with exercises in the basics of creative problem solving and creativity techniques and were allowed to chose the number and types of creativity techniques to solve their problem on their own. From the intuitive creativity techniques, the students selected brainstorming as well as brainwriting, 6-3-5 method and mindmapping. From the discursive methods, some of the students used the morphological box, and some students used creative heuristics such as the SCAMPER checklist, the heuristic principles of the theory of inventive problem solving (TIPS/TRIZ) and creative heuristics from one of the authors/the lecturer (see [8]).

Methods of self-assessment and external assessment were used in evaluating the use of creativity techniques. For the self-assessment, a questionnaire was designed with six Likert items evaluating the feeling of being more creative as a person or a team, enhancement of understanding, ease of use, fun of use and expectation to use the technique again. The items were rated on a Likert scale with five response levels. For the external assessment, Consensual Assessment Technique (CAT) was used. CAT is a method to assess the creativity of a given product based on the assumption that a product is creative if suitable independent observers rate it as creative. A suitable observer is usually an expert in the respective field [9][10]. In this specific case five experts on product creativity evaluated the results of the course. The experts were professors and research fellows of the Düsseldorf University of

[4] Synonymes were taken from the German dictionary Duden: einfallsreich, erfinderisch, erfindungsreich, fantasiereich, fantasievoll, findig, geistreich, genial, gestalterisch, ideenreich, künstlerisch, originell, produktiv, schöpferisch, ingeniös, konstruktiv, innovativ.
[5] The modules were checked for the following established creativity techniques: brainstorming, mindmapping, 6-3-5 method, six thinking hats, morphological box/matrix, theory of inventive problem solving (TIPS/TRIZ) , forced connection and synectics. These techniques cover the main idea-generating principles of association, combination and confrontation and contain intuitive as well as discursive techniques.

Applied Sciences who lecture and research in the fields of new product development and innovation management.

In a second master course held during the summer semester of 2019 (SS2019) the prospective engineers again worked the entire semester of 14 sessions in groups on a self-chosen problem to redesign an everyday object. In total, there were 28 students working in five groups. The students were again trained during two lectures with exercises in the basics of creative problem solving and creativity techniques. This time, however, students were forced to use brainwriting pool as a creativity technique from the category “generation of alternatives” and reversal method/anti-solution as a technique from the category “challenging of assumptions”. This means that the students only used intuitive techniques to better compare the effect of the two categories. For the self-assessment, the same questionnaire as in SS2018 was used again. No external assement was taken to evaluate the creativity of the results, as all the students used the same techniques. Additionally, data was collected on the degree of familiarity with established creativity techniques.

3 RESULTS

3.1 Creativity in Course Catalogs

The results of the assessment of the course catalogs are summarized in table 1. Neither of the analysed universities and universities of applied sciences have a course with the term “creativity” or “creative” in the title. This means that there are no courses in the tertiary institutions in mechanical and process engineering exclusively dedicated to creativity or creative problem solving. In the universities twenty modules (2% of the modules) contained the terms in the module description and ten modules (1%) contained synonymes. In universities of applied sciences only twelve modules (2%) included the terms, but 49 modules (8%) included synonymes. The most common synonym used was “konstruktiv” (constructional) followed by “innovativ” (innovative). This shows that creativity in engineering is often associated with the theory of design (in German: “Konstruktionslehre”).

Table 1. Absolute and relative rate of modules in the respective category

	Category 1: Creativity in the module title	Category 2: Creativity in the module description	Category 3: Synonymes in the module description	Category 4: Creativity techniques in the module description
Universities	0 (0%)	20 (2%)	10 (1%)	2 (0.2%)
Universities of applied sciences	0 (0%)	12 (2%)	49 (8%)	6 (1%)

Creativity techniques were only mentioned in two modules of universities (0.2%) and in six modules of universities of applied sciences (1%). Eight of the ten universities and five of the ten universities of applied sciences do not have a single course with

creativity techniques in the module description. Universities of applied sciences have more courses with creativity techniques which probably reflects their stronger orientation to practical experience ("applied sciences"). The most common techniques were morphological box and TIPS. This also shows that creativity is associated with the design process which is the main area of application for the morphological box. Furthermore it shows a preference for discursive techniques.

Our analysis shows that there seems to be no reflexive examination and deliberation of creativity in mechanical and process engineering. In all the course catalogs analysed, there was not a single course about creativity or creative problem solving. The majority of these tertiary institutions do not even teach creativity techniques – at least they do not advertise it in their module descriptions. As there are courses on innovation management and product development, this indicates that the expectations for engineers are to generate innovation without creativity. The significance of these results is limited insofar as the analysis only focusses on the content of modules and not on the procedure of teaching (e.g. method of instruction, method of examination). However, it could be argued that for an important skill an entire course or a large part of a course should be reserved to enable instruction, reflection and discussion of the subject.

3.2 Creativity Techniques for Prospective Engineers

The results of the self-assessment in SS2018 are displayed in the chart in fig. 2. It shows that intuitive creativity techniques have the highest scores on most criteria. Most of the students think they are more creative personally and in group when they use these techniques (both 1st rank). They also find them fun (1st rank) and easy (2nd rank) to use. So they are likely to use these methods again (1st rank). Discursive techniques fare best in the criteria ease of use (1st rank) and fun (a close 2nd rank). Heuristics show the best result in fostering the understanding of creativity and the creative process (1st rank). The students rank heuristics higher than discursive techniques on the criteria of fostering creativity of individuals and groups, but lowest on the criteria for fun and ease of use.

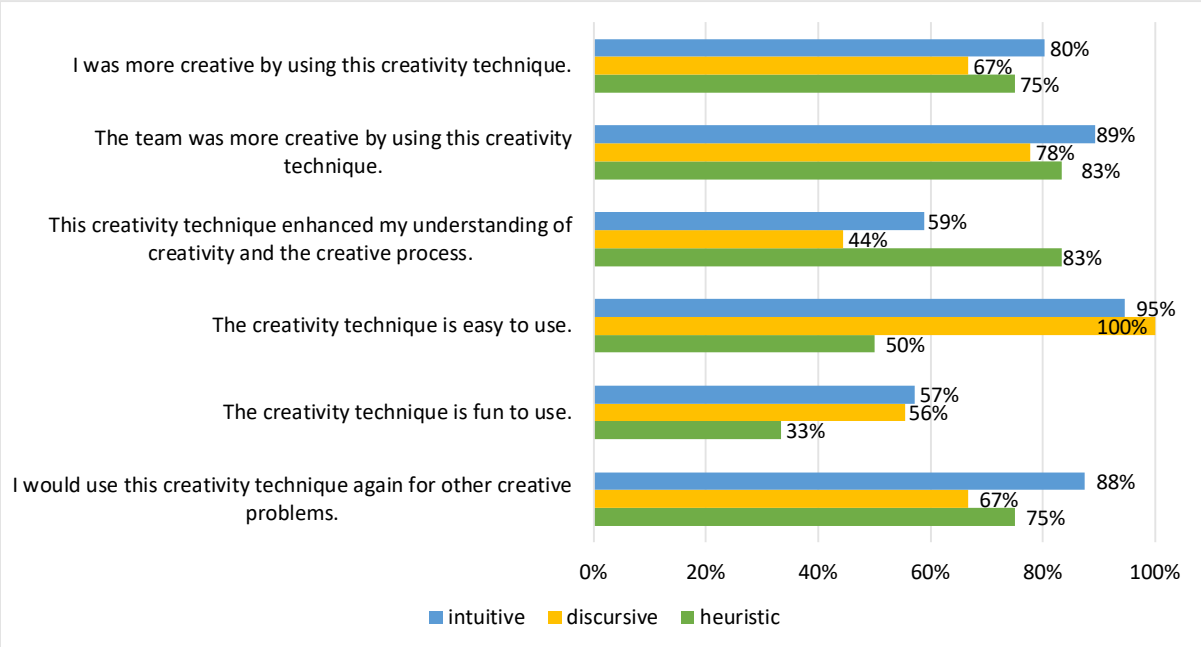

Fig. 2. Self-assessment (SS2018, percentage of answers "agree" and "strongly agree" for students who used the respective creativity techniques)

In the external assessement, the groups who used creativity techniques from several categories fare better than the ones who only used intuitive techniques. The groups who only used intuitive techniques are ranked on the last three places from all eight groups. Especially the combination of intuitive techniques with discursive or heuristic techniques shows promising results. Usually the students used the intuitive techniques first to generate a great number of ideas and then switched to more systematic-analytic approaches to refine their ideas. This result is however restricted by the small number of groups and the fact that not all combinations could be tested, since the students chose the techniques on their own. So there were no groups who chose to use only discursive techniques or heuristics and no group combined discursive techniques with heuristics.

In SS2019 the students were forced to use brainwriting pool and reversal method/anti-solution. So the self-assessment includes only these two methods (see fig. 3). It is strinking that brainwriting is ranked higher on all criteria except for ease of use where both methods achieved almost the same approval. Most students think that brainwriting makes them and their team more creative, enhances their understanding of creativity and is fun and easy to use. Only a minority of students thinks the same for the reversal method. This might indicate a preference of engineering students for methods that generate alternatives over methods that challenge assumptions. As students used brainwriting first and the reversal method after that, the sequence of use might have impacted the assessment. Some students said that the reversal method gave them next to no new ideas after brainwriting.

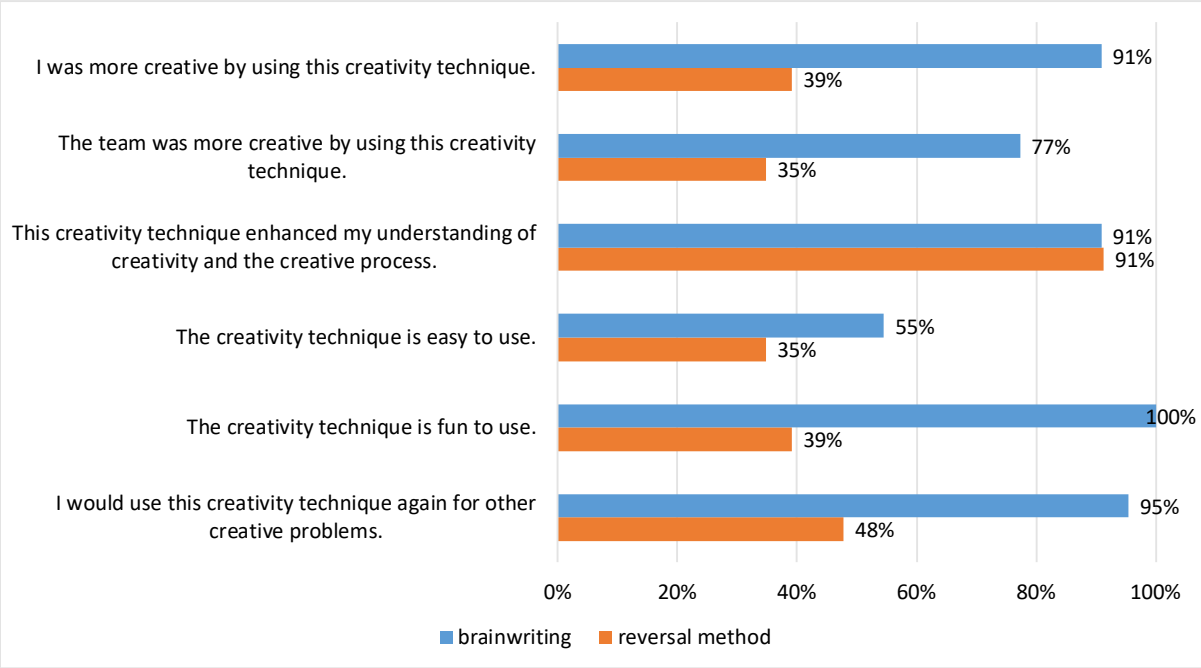

Fig. 3. Self-assessment (SS2019, percentage of answers "agree" and "strongly agree" for students who used the respective creativity techniques)

The assessement of the degree of familiarity in fig. 4 shows that the students are intimately familiar with the intuitive techniques of brainstorming and mindmapping and the discursive technique of morphological box. The latter is often part of the subjects on theory of design in the bachelor study programme. There is only a medium familiarity with the concept of brainwiriting. The familiarity with techniques from the category "generation of alternatives" (brainstorming, brainwriting, morphological box, mindmapping) is much stronger than the familiarity with techniques from the category "challenging assumptions" (reversal method/anti-solution, forced connection, TIPS/TRIZ, synectics and six thinking hats). Especially, there is no prior experience with the reversal method which might have impacted the assessment.

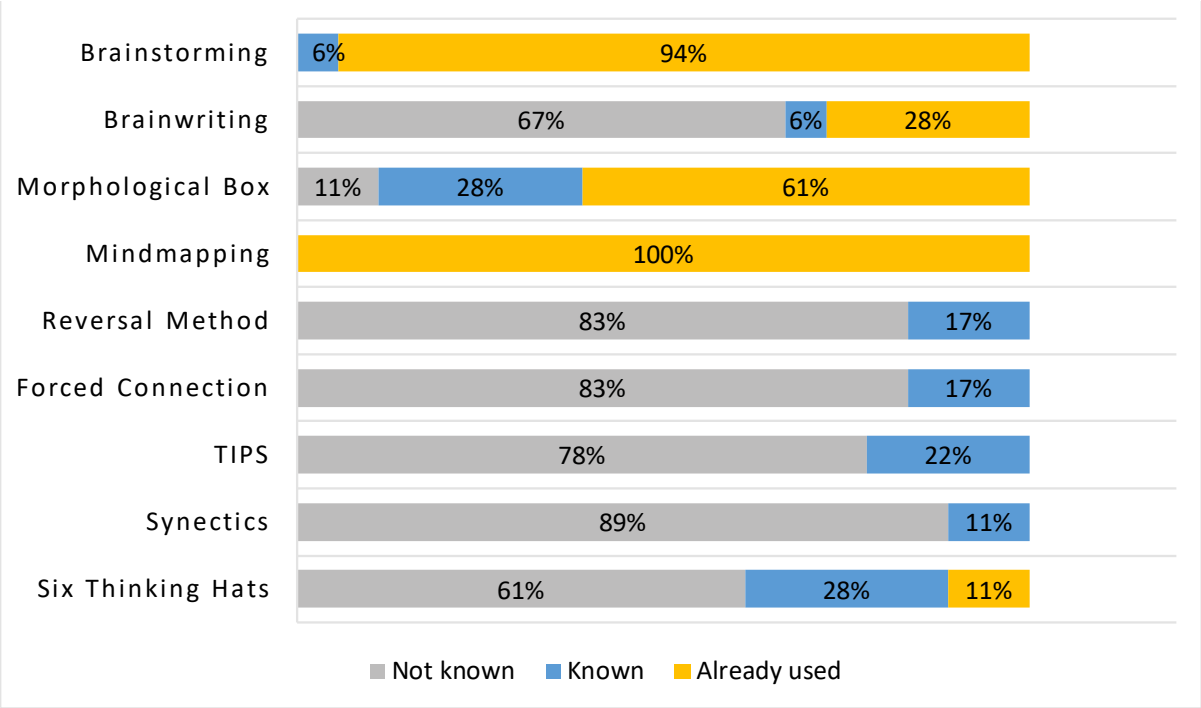

Fig. 4. Degree of familiarity with creativity techniques (SS2019)

Overall, different techniques have different strengths and weaknesses, and a combination of methods from different categories of procedure (intuitive and discursive/heuristic) seems to be most suitable to break up the usual systematic-analytic way of thinking of prospective engineers. The impact of different categories of idea-generating principles (generation of alternatives and challenging assumptions) is still somewhat unclear and needs further clarification.

Engineering students, however, tend to favor discursive techniques and techniques which use generation of alternatives as an idea-generating principle. So, it is important for a course on creativity in engineering to make students try out different methods and reflect on their strengths and weaknesses and on their possible areas of application. The significance of these results is limited insofar as the experiments were imbedded in a regular course with some restrictions in comparison to laboratory conditions (compulsory attendance, grading, free or limited choice of methods, low number of groups). However, the advantage of this approach is that it examines engineering students under realistic conditions over a long period of time on a realistic task instead of a shortterm laboratory experiment under artificial conditions. As Sutherland [11] writes: “True creativity is not thinking of a hundred uses for a brick: it is the ability to solve new problems […]”.

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OPERATIONALISING CHALLENGE BASED LEARNING FOR GEO-INFORMATION SPECIALISTS IN AN INTERNATIONAL CLASSROOM

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Conference Key Areas: *Challenge-based Learning, linking with society*
Keywords: *Challenge-based Learning, international classroom, geo-information students*

ABSTRACT

The main challenge for the new generation of international geo-information specialists is to provide accurate, relevant, and actionable spatial information services to society. Consequently, educators need to organize their education in such a way that students students not only to master content, but also acquire essential skills and competencies to collaborate, communicate, and think in a critical, creative, and innovative manner. The concept of Challenge-based Learning (CBL) provides a flexible and effective educational framework for finding a collaborative solution to real-world, open-ended, technology-driven challenges in interdisciplinary teams. A perfect example of a task that our students will face in their professional life, is providing adequate geo-information services to application fields outside of their expertise.

At the Faculty Geo-Information Science and Earth Observation, University of Twente, the classrooms are highly international (from 75% to 100% non-European) and from multiple application fields. MSc students are highly motivated, especially when they can tackle challenges linked to their home countries. By operationalising the CBL concept we want to enable students to co-define their learning path, to enhance 21st-century skills in an international classroom, and to exchange experience with peers and experts, while acquiring essential domain knowledge. In spring 2020, we will embed a CBL approach in an online elective called “Weather Impact Analysis”. In this concept paper, we show how, by using the CBL approach, students obtain deep domain knowledge and skills, while at the same time they acquire 21st-century skills necessary to succeed in a rapidly changing society.

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1 INTRODUCTION

We live in a is changing world; its climate is changing as well as human pressure on natural resources. This makes that skills and knowledge acquired by graduated students necessarily need to change in order to tackle global challenges. Universities and her academic staff will have to rethink their learning environments (learning resources, technology, modes of learning, roles of teachers and students, etc.). We developed a new MSc elective course for a small international classroom, which required a teaching method that allows students to take ownership of their individual learning process. We realized that students should go through four stages of self-organised learning: sensing/feeling, watching/reflecting, thinking and doing (Fielding, 1994). At the same time, there were four boundary conditions to be considered: 1) it is an international classroom (over 75% foreign), 2) it is an multi-disciplinary classroom, 3) students should get ample training in scientific reasoning as their next study phase is the MSc research, and 4) due to the COVID-19 virus and timing of the elective (April-June 2020) it should be taught fully online.

The Challenge-based Learning framework (CBL) provides an environment where skills and content can meet, as teaching is focused on solving real-world challenges (Nichols et al., 2016). CBL is founded on the Experience learning theory of Kolb (1984) and is based on the belief that students learn best when they learn by experience. Implementation of the CBL framework offers students the opportunity to focus on the personal development of knowledge and skills, while improving key competencies for the 21st-century working environment such as interdisciplinary and intercultural communication, collaboration, decision-making, as well as critical thinking. Although students will work in groups, the learning outcomes will need to be reached on an individual basis (Rådberg et al., 2015).

For the new MSc elective course “Weather Impact Analysis”, we adopted the CBL framework of Nichols et al. (2016) for its project work. The objective of this concept paper is to provide a design for this online elective using a CBL approach, while maintaining a balance between exposure to CBL skills, enhancing academic skills, and building new domain knowledge and analytical skills. This set of 21st-century skills, complemented by discipline knowledge, is considered essential for students in their MSc research stage as well as in their professional life after graduation. The presented structure is developed to support teaching staff, that is not familiar with CBL, in their role as course developer and teacher, and want to adapt CBL in their domain knowledge courses.

2 DESIGN AND IMPLEMENTATION OF CBL APPROACH

The course Weather Impact Analysis has four main learning outcomes: by the end of the course, students should be able to understand how weather impacts society (LO1), evaluate suitable datasets to analyze both weather and impact (LO2), explore analytical tools to extract relevant information from the datasets (LO3), and

incorporate new domain knowledge in a CBL context (LO4). The course consists of two parts: first specific domain knowledge and analytical skills concerning extreme weather impact are taught, and subsequently small groups of students work on a real-world challenge. During this project work, students will need to use their freshly acquired domain knowledge and 21st-century skills to find an optimal solution. The assessment methods are an inception presentation and a report, of which the criteria are in line with the learning outcomes.

The international classroom during the first year of the course (2020) contained 10 MSc students, a mixed population of European and non-European as well as a mixture of academic backgrounds. None of these students had an academic background in atmospheric sciences, so domain knowledge for analyzing extreme weather events and their impact on society was provided in the first part of this course. The teaching staff was scientific experts in various domain fields, supported by an educational consultant. Staff involved are highly experienced with didactic concepts for international classrooms, which makes raising cultural awareness an implicit part of all steps in the educational structure presented below. To ensure the balance between domain knowledge and CBL skills, the role of the teacher in this project phase had to be dual: domain expert with facilitation skills.

Figure 1 shows the newly developed basic course design for the project work, where teachers and students didactics meet to build towards the learning outcomes strengthened by CBL skills. Within the course, both students and teachers have various tools for self-reflection and instruction, allowing a personalized learning process. The adopted CBL framework by Nichols et al (2016) consists of three phases: Engage, Investigate, and Act. Within the course we translated these phases as “to understand the challenge”, “to explore the possibilities by analyzing information”, and “to solve the challenge by presenting a working solution”.

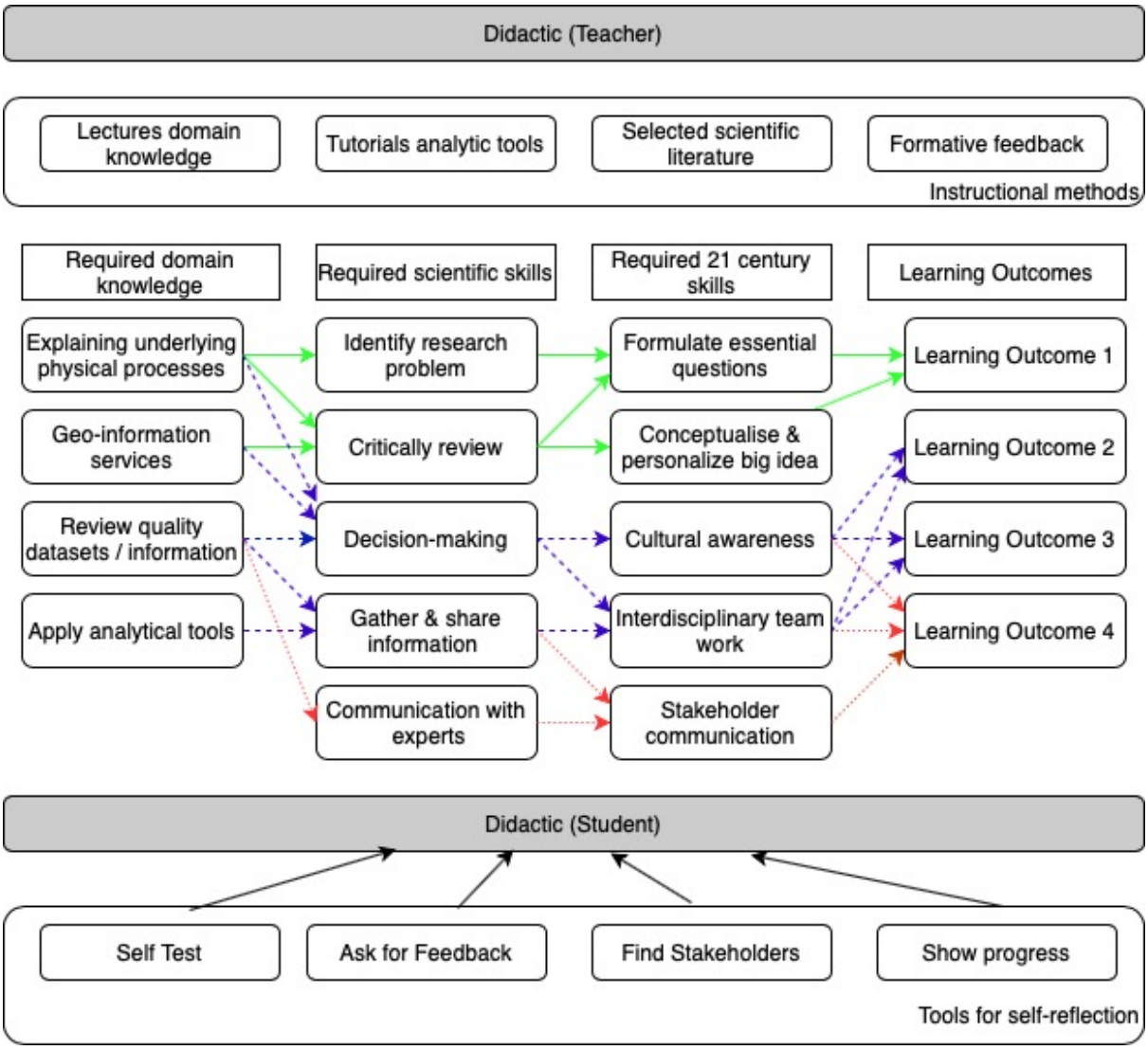

Figure 1 Educational structure showing relationships between the didactic activities of teachers (top) and students (bottom) with respect to maintaining a balance the required domain knowledge, required domain skills, 21st-century skills, and the learning outcomes. The solid green arrows refer to CBL phase Engage, blue dashed arrows to CBL phase Investigate, and dotted red arrows to CBL phase Act.

The first phase, ENGAGE (solid green arrows), requires the students to explore a real-world challenge and develop essential questions to show a deep understanding of underlying processes and research done by others, and narrow the challenge to a research question. In the second phase, INVESTIGATE (blue dashed arrows), students are to formulate guiding questions. They discuss within their teams what resources (knowledge, data, and analytical tools) to select for investigating a variety of solutions. In the last phase, ACT (dotted red arrows), students generate possible solutions, discuss these with experts and stakeholders, and present an “optimal” solution to the original plan.

The figure shows that the second and third phases depend on similar skills and knowledge, because students might have to redefine their information and data services after reflecting on their possible solution to the real challenge. Students document, reflect, and share every step of the process on the progress made. Open formative evaluations are planned to ensure students reflect and communicate on their steps in the individual learning process with their peers and experts.

3 EXPECTED RESULTS

We envisage that our CBL framework, and the experience we will gain during the delivery of the course, will result in a workable course design for implementing CBL effectively in an international classroom. Within the faculty ITC, this course will be the first domain knowledge MSc course that has a CBL framework embedded, and where domain knowledge and CBL skills have to be balanced and evaluated. During the execution of this course, special attention will be given to the individual learning experiences of the students. Although the student population will be around 10, we are curious to find whether there are similarities or differentiation between various cultures, MSc programs, or other factors.

Compared to regular domain project work done within the two MSc programs, we expect that students will, at the end of the course, be better prepared for tackling real-world challenges that are connected to academic content. The CBL structure presented allows students to explore their interests in a variety of ways, where intercultural, international, and interdisciplinary perspectives play a role in finding solutions for big global challenges. The students will be prepared to implement newly gained domain knowledge into a real problem, explore possibilities, and communicate their optimal solution.

While operationalizing CBL in an international classroom, we do not expect that cultural interplay, respect, and acceptance will be a major challenge. All teaching staff has large experience in teaching international classrooms. Also, the students have been exposed to other cultures and disciplines for about a year already. We believe that the success of CBL implementation even benefits from the international classroom, where intercultural awareness plays an implicit role when having to share, document, and reflect on their work.

During and after the course, the presented structure will be evaluated and adopted. Although the course will be completely online, we do not expect major adjustments when delivering this course physically in class again. At the SEFI conference, we expect to present the improved version, such that our design can be used by other domains, also outside the geo-information sciences.

4 SUMMARY AND ACKNOWLEDGMENTS

Maintaining the balancing between disciplinary knowledge, academic skills, and CBL skills will be crucial to prepare MSc students for the research stage as well as for their professional careers. A common factor is that none of the students has an academic background associated with the main topic of the course, i.e. weather impact. This concept paper provides a generic structure for a course design where domain knowledge and skills, as well as the 21st-century skills are integrated. At the conference, we will share our experiences on how adopting a CBL approach in a scientific teaching environment worked out in practice.

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TRAINING STUDENTS TO CROSS BOUNDARIES BETWEEN DISCIPLINES, CULTURES, AND BETWEEN UNIVERSITY AND SOCIETY: DEVELOPING A BOUNDARY CROSSING LEARNING TRAJECTORY

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Conference Key Areas: *Interdisciplinary education, Diversity and inclusiveness*
Keywords: *boundary crossing, interdisciplinarity, learning trajectory, learning activities, curriculum*

ABSTRACT

The competence to work together and co-create with others outside one's own scientific domain, institute, and/or culture, is a critical competence for future engineers to respond to emerging global challenges. In this context, Boundary crossing (BC) competence is crucial. In a university-wide Comenius Leadership project we currently develop BC learning trajectories for various study programmes that aim to foster BC competence development by explicating and aligning BC learning activities. Within the context of this project, we focus on *disciplinary, cultural,* and *university-society* boundaries, but consider these to be exemplary for other boundaries.

Our fundament is the boundary crossing theory of [1] and its four learning mechanisms (identification, coordination, reflection, transformation) representing catalysts for learning. In this concept paper we explain, what boundary crossing competence is, why it is important for engineers, and what steps to take towards BC competence development in a study programme. In our oral presentation we will explain how we operationalised these mechanisms into concrete educational tools: the BC-rubric for explicating learning across boundaries, a blueprint learning trajectory, and a tool to be used in teacher teams to identify BC learning activities in curricula. We will share examples of BC learning activities and their alignment into curricular learning, and how we aim to assess and monitor the implementation of the BC learning pathways and their effects on students and teachers.

This concept paper gives a solid fundament for engineering educators to critically reflect on how they explicitly address, coach, assess and further develop students' boundary crossing competence required for the engaged engineer.

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1 BOUNDARY CROSSING: AN INTRODUCTION

Boundary Crossing (BC) competence is regarded as one of the major competencies of future engineers to respond to emerging global challenges. In this concept paper we define BC Competence as the ability to recognize, seek, appreciate and utilize the tensions arisen when different perspectives and positions come together. To contribute to students' BC competence development and to further improve and implement boundary crossing experiences, a three-year university wide project was granted a Comenius Leadership Fellow. This Comenius project aims to (1) develop a conceptual foundation for the development of BC competence, (2) design and implement learning pathways, and (3) compile a BC toolbox for and with lecturers, course coordinators, and management.

This conceptual paper aims to answer the questions "what is boundary crossing competence", "why is boundary crossing competence important for future engineer", and "how can BC competence be supported and strengthened in academic education". In Annex 1 we provide examples of boundary crossing learning outcomes, activities and two learning trajectories developed by two of the programmes participating in the Comenius project. These examples aim to make the theoretical concept more tangible in educational practice.

2 WHAT IS BOUNDARY CROSSING AND BOUNDARY CROSSING COMPETENCE?

A boundary is a tension or challenge experienced when people from various practices (e.g., a discipline, culture, or organisation) meet or interact [2]. One can experience such a tension or challenge for instance when collaborating in a project with a diverse group of people. When boundaries remain implicit and the 'other' perspective is ignored in favour of one's own perspective, interaction and collaboration are hampered. When boundaries are made explicit and the 'other' perspective is placed side by side or even integrated within one's own perspective, interaction and collaboration are facilitated and sought for, and the creation of new, transformative outcomes are made possible. BC is needed to enhance collaborative processes, to change routine behaviour or procedures and to come up with new ideas, products, or solutions. As such, boundaries and boundary crossing create great opportunities to learn and BC can contribute to the personal development of those involved in the learning process [2].

BC competence refers to the *ability to cross boundaries between one's own and others' practices and perspectives with the aim of making new connections, learning from 'the other' and co-creating new practices* [1] (see Box 1). Crossing boundaries requires the people involved to explicate and explore the boundaries, to engage in a constructive dialogue, in order to integrate various perspectives and to develop new hybrid or transformed practices.

Box 1. Definitions

Boundary Crossing	Efforts people take to collaborate across different practices and perspectives.
Boundary Crossing Learning Mechanism	A process evoked by boundaries that can enhance learning across boundaries.
Boundary Crossing Competence	Knowledge, skills, and attitude that enable a person to recognize, seek, appreciate and utilize boundaries

3 WHY IS BOUNDARY CROSSING COMPETENCE IMPORTANT FOR ENGINEERS?

BC competence is crucial for engineers able to address global, sustainability challenges. Providing access to clean water, increasinf the use of solar energy, managing nutrients cycles cannot be achieved by individuals or single agencies, neither can this be done within one discipline or culture. Facing these grand or wicked challenges requires multi-, inter- and transdisciplinary approaches in international and multicultural contexts. It requires bridging academia and society, disciplines, cultures, and perspectives. BC competence is crucial in such settings. Universities that aim to deliver graduates who are able to help resolve these grand challenges, should focus their education not only on a particular study domain; they should also train their graduates to become good “boundary crossers” (see Box 2); they should train their graduates to be able to collaborate and co-create new practices with a wide diversity of people.

Box 2. A good ‘boundary crosser’

- considers what expertise is needed to successfully perform (in) a project (challenge, assignment, or task);
- is aware of his/her own identity and qualities, but also sees what the limitations are of his/her own perspective and qualities;
- is open and actively searches to contact and learn from other people (i.e. people from other practices, cultures, disciplines, or organisation) and sees the advantage of using these people’s perspectives and expertise;
- facilitates and stimulates the collaboration of people involved in a project;
- empathizes with other people’s perspectives, interests, or ideas, also when they differ from his/her own;
- explicates how various expertise, multiple perspectives, and interests are used and integrated in a project to deliver a better result;

- sees tensions not as something to avoid at all cost, but as a potential source of learning, creativity and change;
  learns from the BC experience and encourages other people to reflect and learn as well.

4 BOUNDARY CROSSING LEARNING MECHANISMS

Boundaries evoke processes that can trigger learning. Learning is meant here in a broad sense as a change in thinking that results from a form of dissonance [3]. It may result in better acknowledging and appreciating one's own expertise and perspective, but also in adopting new approaches or new ways of doing something or co-creating something new. Effective BC requires efforts and skills from the people involved. Four learning mechanisms are essential in crossing boundaries: *identification, coordination, reflection* and *transformation* [1].

- *Identification* - Identification is becoming aware of one's own expertise as well as of one's own assumptions, values and principles and of how they influence the way one sees and interprets what is going on. Identification is also about recognizing that your way of seeing and interpreting of what is going on can be different from the way others do. For students, identification is important, because it enables them to better specify who they are, what their expertise is, and what their personal norms and values are in relation to those of others. As such identification might contribute to appreciating other people's expertise and perspectives, and to the learning potential of boundaries.
- *Coordination* - Coordination refers to effectively collaborating. It refers to finding means and procedures to effectively work together. Coordination implies that students initiate and organise meetings with relevant people (other students, municipalities, companies), make working agreements, and seek ways to effectively communicate across various practices/boundaries. Boundary objects, that is tools that can facilitate more effective communication across practices (like a portfolio, notes, a collaborative designed mind map) can be helpful in this stage.
- *Reflection* - Reflection refers to perspective making and taking. It refers to trying to see the world or one's own practice through the eyes of somebody else, such as a student with a different cultural background, or the client of a consultancy project. Reflection enables students to widen their perspective. It contributes to students' appreciation of a variety of perspectives and practices and willingness to learn from each other's perspectives.
- *Transformation* - Transformation refers to change in action or practice as a result of judging and utilizing a variety of perspectives and expertise; it refers to really doing something new or differently, such as changing personal behaviour as a result of appreciating and incorporating a new norm, value, or perspective. Transformation also refers to collaboratively, co-creating new concepts, new routines or procedures, new, hybrid practices, or innovative solutions.

The four learning mechanisms are illustrated in Figure 1 including questions asked when adopting or triggering the learning mechanism.

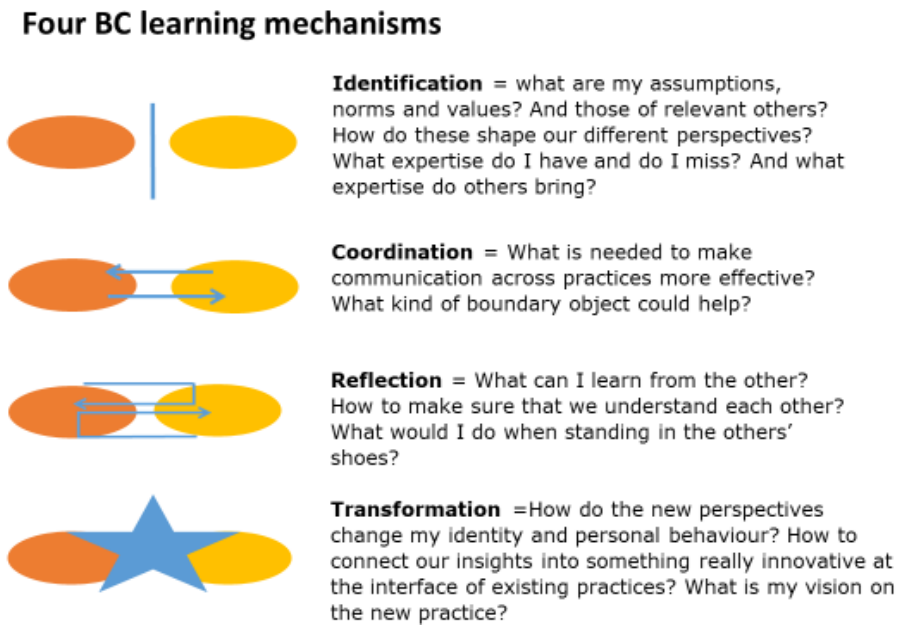

Fig. 2. Boundary crossing learning mechanisms and related questions (based on [4])

5 BOUNDARY CROSSING COMPETENCE: A GENERIC ACADEMIC COMPETENCE

BC competence is a generic competence that can be applied in a variety of contexts, in and outside academia, when faced with a variety of boundaries. Typical for the academic context are challenges that emerge from being educated in a particular scientific domain or operating in an academic context. When studying at a university, students engage in a particular practice, they learn scientific paradigms, theories, methods and approaches of their own study domain. When they advance in their studies, they usually become more specialized and more advanced in their academic practice. Often, they don't realize this until they experience challenges in collaborating with people from another disciplinary, cultural, or educational practice; until they experience boundaries. Academics can also experience boundaries when they collaborate with people from outside academia, when they need to translate scientific knowledge to laymen, or when they are involved in a policy debate (e.g., on climate change or vaccination), and have to defend the importance of scientific knowledge and approaches.

Within the context of the Comenius Leadership Fellow project, three kinds of boundaries have been identified as exemplary: *disciplinary, cultural* and *university-society* boundaries. Obviously, these are not the only boundaries that one can encounter. These boundaries have been selected because they explicate a specific context to practice BC competence. As such they can help programme management and lecturers recognize the necessity to address BC in their courses and to include

learning activities that address the BC learning mechanisms. By letting students practice the use of the BC learning mechanisms in a variety of learning situations, they become better equipped to deal with any kind of boundaries they will be faced with in their future lives.
Boundary crossing can happen at the institutional, interpersonal and intrapersonal level [4]. Boundary crossing at the *institutional* or organisational level (i.e. when organizations of organizational units interact and consequently redefine their characteristics or identity) is beyond the scope of this paper. Boundary crossing in this paper focusses on learning from and with people from other practices at the interpersonal or intrapersonal level. BC at an *interpersonal level* is about interaction among people from different practices, such as researchers, students, or stakeholders with diverse backgrounds, aiming to collaboratively integrate different perspectives into new ideas, practices, innovations. BC at the *intrapersonal level* relates to the personal development of a student. By incorporating ideas and new perspectives from other practices, a student's identity, being, or behaviour might change. BC at the intrapersonal level influences a students' thinking, doing, and communicating [4]. Both interpersonal and intrapersonal boundary crossing is, or should be, part of engineering study programmes.

6 TRAINING BOUNDARY CROSSING COMPETENCE

Engineering education might offer already a variety of opportunities to practice BC. Often students from various educational backgrounds and from all over the world jointly follow lectures or collaborate in group or lab work. These students might experience boundaries when they collaborate with students from other study programmes, or from other nationalities or cultures, or when they collaborate with non-academic stakeholders. *Offering students a setting* in which a variety of boundaries can be experienced is, however, insufficient to enable fruitful BC learning. Just putting students in an intercultural group and expecting that magic will happen, is naive. Sending students on a field trip will not automatically result in students experiencing the differences between their perspectives and those of companies, consumers, or other societal actors, and thus not automatically turn into a meaningful BC learning experience. *BC competence development requires explicit support and reflection*. Just like any other competence (e.g., academic writing), BC competence needs to be explicated and trained; it needs to be practiced and developed throughout a university study programme [5,6].
Students can develop their BC competence by engaging in a variety of learning activities that require them to apply the four learning mechanisms in a variety of situations. These situations can (should) differ in the *type of boundaries to cross*, the *number of boundaries*, the *'difficulty' of (crossing) the boundaries*, and probably the focus on more or less mechanisms, e.g. Identification (I), Coordination (C), Reflection (R), or Transformation (T).
It is important to note here that not all courses in a study programme need to go through all the four I-C-R-T learning mechanisms. Moreover, these I-C-R-T learning

mechanisms do not have to be experienced in sequential order, and transformation does not have to be the ultimate learning mechanism for every course. In some courses, for example, focussing on identification might be a desired learning outcome. In such a course, students learn to get to know themselves, their strengths and weaknesses and they learn to entangle the qualities that are needed for solving the problem at hand, and thus they learn to adopt the identification mechanism. In another course, students can be stimulated to start off with envisioning an ideal future (i.e. transformation) and then to examine how their various disciplinary backgrounds can be used in creating this ideal picture (i.e. identification and reflection). Although not all four I-C-R-T learning mechanisms need to be addressed in a course, it is important that they are *all explicitly addressed several times and in a variety of learning situations throughout a curriculum*.

7 HOW CAN BOUNDARY CROSSING COMPETENCE DEVELOPMENT BE SUPPORTED AND STRENGTHENED IN ENGINEERING EDUCATION?

BC competence development can happen 'anytime anyplace', also outside the classroom in all kind of extracurricular activities such as *Studium Generale* or student challenges, but also in sports, music clubs, or when diverse students are living together. However, simply being confronted with boundaries, does not mean that students utilise these boundaries to learn, co-create or develop. As we said before, a more natural response of many people will be to avoid tensions without crossing them. To ensure, that all students develop BC competencies, BC competence development should be embedded in their study programmes. Seeing boundaries as learning opportunities and BC competence development requires structured and explicit attention in assignments, courses and curricula [7]. BC competence needs to be *instructed*, *practised*, students should give and receive *feedback* on their BC competence, and their BC competence needs to be *assessed*, preferably in a variety of courses.

To develop BC competence within a study programme a *BC learning trajectory* can help. A learning trajectory consists of: (i) learning outcomes, identifying several levels of boundary crossing (= the what) and (ii) a series of aligned learning activities to which students are exposed to in order to develop towards these levels of boundary crossing outcomes (= the how). Such a learning trajectory includes instruction, practice, feedback and assessment. To acquire BC competence, it helps when students are exposed to a variety of BC situations (i.e. different contexts, different types of boundaries) to learn to recognise boundaries (of any kind or type) and learn how to handle them in a good way. *Learning activities* that explicitly address BC learning mechanisms and trigger BC competence development are thus needed (see Box 3).

Box 3. Heuristics for boundary crossing learning activities [8]

BC competence development requires:

- Experience, being involved in addressing a real-life complex issue and applying disciplinary and interdisciplinary methods, techniques, and procedures to integrate solution-oriented knowledge.
- Close collaboration in a team of which its members have a diverse (e.g., disciplinary or cultural) background.
- Explicit moments of perspective switching (e.g., specialist, integrator, stakeholder).
- Field work, to integrate classroom-based knowledge in a specific context, to transcend disciplinary knowledge, and to experience the 'complexity' of reality.
- Interaction with stakeholders outside academia and facing the differences in norms and values held by the societal actors and oneself.
- reflection on the research process, the role of science and the role of norms and values in addressing a societal problem.

The questions below are meant to trigger programme committees, programme directors and lecturers' thinking about boundary crossing within their curricula. They are meant to trigger their thinking about what boundaries they want their graduates to be able to cross, where and how boundaries and boundary crossing is part of their programme, and what (new) learning activities can be designed to explicitly address the I-C-R-T learning mechanisms at various stages of the programme. Thereby, these questions help to work towards a BC learning trajectory that fits a specific educational programme.

1. *Doing an inventory of current BC experiences in a curriculum*:
   - Where in your study programme are boundaries present?
   - Are these boundaries utilized as learning opportunities?
   - Are explicit learning activities used to help students crossing the boundaries? If so, which ones?
   - Is BC instructed, practised, is feedback given, is BC assessed?

2. *Identifying boundaries*
   - What boundaries do you expect your graduates to be able to cross? And thus, what boundaries should your students be confronted with during your study programme?
   - Which boundaries do you want your students to practice crossing?
   - Does your programme aim at developing BC at interpersonal or at intrapersonal level, or at both?

3. *Selecting courses that will explicitly address the I-C-R-T learning mechanisms*:
   - Which courses are suitable for *instructing* students on BC and BC learning mechanisms; which ones for *practicing* I-C-R-T learning mechanisms; which ones for giving and receiving *feedback*; which ones for *assessing* BC competence?

- Which courses are suitable to develop BC at interpersonal level? Which courses are suitable to develop BC at intrapersonal level?

4. *Developing new learning activities that explicitly address the I-C-R-T learning mechanisms, including instruction, practice, feedback, and assessment.*
   - How can you change existing learning activities to make more explicit use of already present boundaries?
   - What new learning activities can you design?

Once these questions are addressed, learning activities and assessment tools need to be developed. One of the outcomes of the Comenius project is the development of a toolbox for learning activities and assessment tools. Some examples are presented in Annex 1, more practices will be shared in the oral presentation.

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Annex 1: Examples of boundary crossing learning outcomes, activities and learning trajectories

To make boundary crossing more tangible, this section will display some exemplary BC-learning outcomes, learning activities and learning trajectories developed in various Bachelor and Master programmes of our University.

Exemplary learning outcomes

Boundary crossing learning outcomes are often, and can easily, be linked to the more content related learning outcomes of a course. The examples below show a variety of learning outcomes. After every learning outcome we will show 1) the name of the programme, 2) the year of study, 3) the addressed boundary crossing learning mechanism(s), and if applicable 4) the type of boundary at stake.

- Know what is interdisciplinarity in the food domain and recognize this for different phenomena (BSc Food Technology, year 1/period 1, identification, disciplinary boundary);
- Integrate theoretical and practical knowledge from various food science disciplines while considering the consumer perspective as well (BSc Food Technology, year 1/period 6, identification/transformation, disciplinary and university-society boundary);
- Communicate project progress with various stakeholders (BSc Food Technology, year 1/period 6, coordination/reflection, university-society boundary);
- Assess and analyse land use and water management issues from different academic and societal perspectives and bring these together (BSc International Land and Water management, Year 1/period 1, reflection/transformation, all kind of boundaries);
- Create additional value by combining biobased disciplines thus to apply an interdisciplinary approach (MSc Biobased Sciences, Year 2, identification/reflection/transformation, disciplinary boundary);
- Work as part of a multi-disciplinary and multicultural team and value the contribution of different perspectives in designing solutions for complex (environmental) problems (MSc Environmental Sciences, year 1/period 6, identification/coordination/reflection, disciplinary and cultural boundary).

Exemplary learning activities

We can also make boundary crossing more tangible in learning activities. Below we present some learning activities that can be integrated in any kind of course. They are described independent from a specific context or educational program. The table shows what type of boundaries are crossed, possible variations to the learning activity and the addressed boundary crossing learning mechanism(s) .

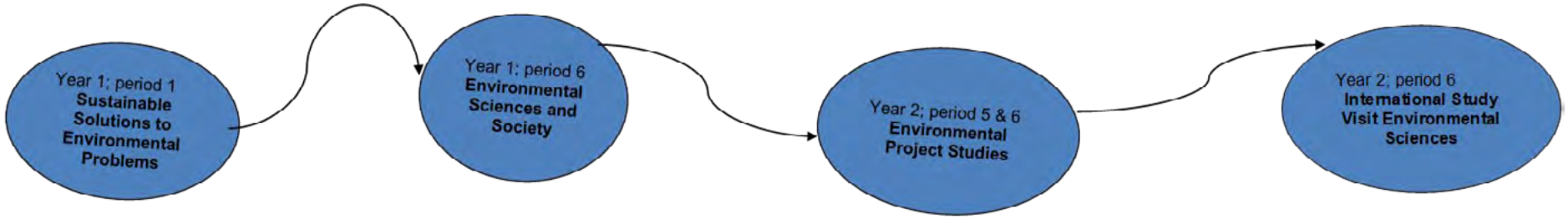
Title	Core of the activity	Boundaries addressed	Possible variation /addition
Debating different perspectives	Assign students roles of different stakeholders from who's viewpoint they participate in the debate	University-society Possibly different disciplinary perspectives	Let students prepare their own stakeholders perspectives more or less thoroughly with/without guiding questions <u>BC-Learning mechanism:</u> Identification, Coordination & Reflection
Exploiting cultural group diversity in a poster market	Take a controversial topic relevant to the course (e.g., animal welfare, Palm oil, water conservation) Let students from different countries/cultures explicitly elaborate on the topic from their national & cultural perspective. Every student prepares a poster. In a poster market session students share perspectives. After the market intercultural groups develop a shared poster showing the topic from all different perspectives.	Cultural and international	Provide guiding questions to be addressed on the poster Let individual students elaborate their own poster with new insights gained from the other posters. Ask individual students to express (orally or verbally) how their own national/cultural perspective is challenged by the others: how is your own opinion on the topic changed? <u>BC-Learning mechanism:</u> Identification, Coordination & Reflection
Including multi-perspectivity in field visits and excursions	Offer students a list of critical questions to be asked to the societal stakeholder they visit to identify the stakeholder's perspective on a course relevant topic	University-society	**A.** <u>Prepare:</u> Let students first explicate their own perspective on the topic: What do they currently know about this issue? How do they feel about it? **B.** <u>Prepare:</u> Let students individually or in groups prepare a list of critical questions to ask the societal stakeholder to grasp their perspective **C.** <u>Afterwards:</u> Let students together visualise trade-offs between identified perspectives (including their own) <u>BC-Learning mechanism:</u> Identification, Coordination, Reflection
The boundary crossing portfolio	Students reflect on their own experience and developments regarding interdisciplinarity. They will create a portfolio with reflection papers written at X moments during the study programme Students have to defend their reflection in a final interview.	Disciplinary	Other boundaries, relevant for the study program, can be integrated <u>BC-learning mechanisms:</u> reflection, (intrapersonal) transformation

Developing a concept map using colour coding	Student groups collaboratively develop a concept map on certain topics using colour coding: Step 1: individual concept map (blue pen) Step 2: elaborate 1 individual map with additions form other maps (red pen) Step 3: let students study the topic from a certain perspective (in books, articles, internet) Step 4: further elaborate the map with the theoretical insights (green pen)	Depending on the assigned perspectives in step 3.	A. Let students identify different disciplinary influences in their own perspective in step 1 B. let student draw an individual concept map afterwards, showing their (changed) own perspective <u>BC-Learning mechanism:</u> Identification, Coordination & Reflection

Exemplary learning trajectories

This final section shows two exemplary BC-learning trajectories as currently developed in two of the Bachelor Programmes participating in the Comenius Leadership Project. Both examples show the learning trajectory by visualising the line of courses that make up the trajectory. Per course, the addressed boundaries are described, next to the learning outcomes of the course and some examples of learning activities adopted in the course to explicitly address boundary crossing.

Boundary Crossing Learning Trajectory BSc Environmental Sciences



Course and its core theme	**Sustainable Solutions to Environmental Problems** Learning that the synthesis of social science and natural science helps to generate new interdisciplinary solutions to wicked environmental problems	**Environmental Sciences and Society** In this thematic course the Animal Consumption and Production Chain is used to show how knowledge from different scientific disciplines and stakeholders contributes to analysing, solving, and preventing environmental problems, and to creating sustainable solutions.	**Environmental Project Studies** A group-wise research project investigating an environmental issue emanating from professional practice. Due attention is paid to the societal aspects of the researched topics, the role of science, and the development of the students' own view on the approach of environmental problems.	**International Study Visit Environmental Sciences** Wageningen University students collaborate with students and staff of another university outside the Netherlands (Ukraine, Estonia) on a two week research project/case study. The main theme Restoration of semi-natural habitats/ Nuclear power is approached in a multi-disciplinary way.
What boundary / boundaries are addressed in the course?	Disciplinary University-Society Cultural	Disciplinary University-Society Cultural	University-Society More specific: Between the commissioner's assignment and (university) course assignment for a lecturer; Between different parties judging the research proposal/report (the commissioner and the lecturer);	Disciplinary Cultural

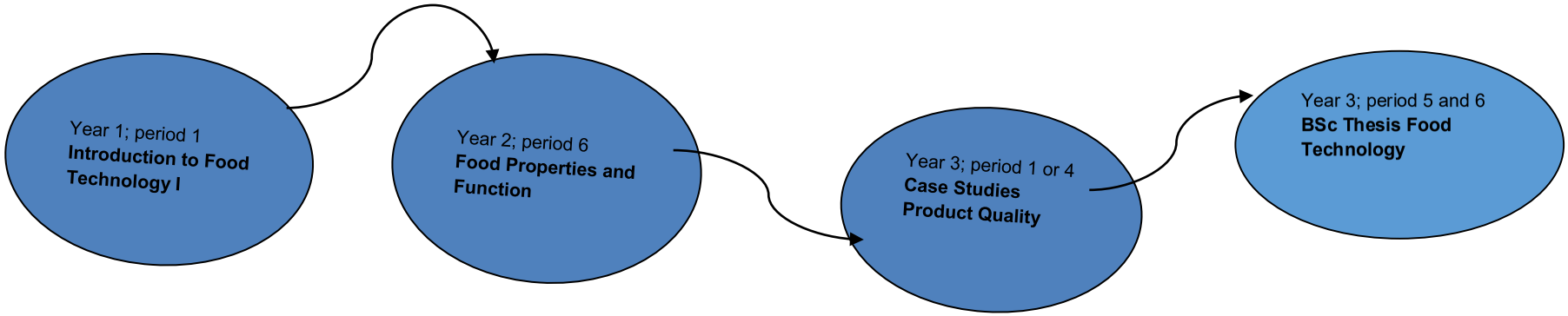
			Between theory and practice; Between different drivers or stakes, such as attention for environmental/sustainability issue versus an economic/financial issue; Between skills/knowledge/expertise from different students (based on background).	
What BC learning mechanism are addressed? ○ Identification ○ Coordination ○ Reflection (perspective making /taking) ○ Transformation	• Identification (of disciplines and stakeholders) • Coordination • Reflection • Transformation *All on a very basic level*	• Identification • Coordination • Reflection (perspective making and taking on stakeholder assignment and perspectives) • Transformation	• Coordination (communication with real life commissioner and stakeholders) • Reflection (on societal aspects of an environmental problem and team work)	• Identification • Coordination • Reflection
BC learning objectives of the course (as part of the complete set of learning objectives)	*1. understand that environmental problems need to be approached from different natural and social scientific disciplines;* *2. explain the features of interdisciplinary scientific research;* *3. analyse an environmental problem and integrate theoretical and practical knowledge (incl. stakeholder's perspectives) to develop a sustainable*	1. explain what Environmental Sciences is. *2. analyse environmental problems triggered by the Animal Consumption and Production Chain and the underlying societal trends, using visions, knowledge and methods from different (scientific) disciplines.* *3. evaluate how technological, natural and social sciences*	1. acquire experience with planning and execution of an environmental project; *2. acquire understanding of the societal context of environmental research and the societal backgrounds of environmental problems;* 3. are capable of collecting, processing and reporting of information; *4. are capable of co-operating in a group and can evaluate this co-operation;* *5. initiate and sustain contacts with their supervisor and commissioner;*	*1. evaluate multiple dimensions of an environmental problem abroad;* *2. collaborate within a group work, in consultation with experts from abroad, such as faculty members and students from the host institution and relevant stakeholders;* 3. apply knowledge, methods and tools of environmental sciences in a case study abroad;

	solution for this problem; 4. combine different sources of information and develop a synthesis; *5. identify how cultural perspective influence one's role in the group and one's take on environmental issues;* 6. write a clear and well-structured report; 7. present and defend the key features of the report.	*contribute to solving and preventing complex environmental problems.* *4. collaborate in a multi-disciplinary and multicultural team, including literature research, writing and field research, and communicating findings orally and in writing.* 5. explain what the specializations of the Environmental Sciences program are, the aims of these specializations and the possible professions.	6. train themselves systematically in conducting meetings, including the preparation, chairing, the writing of minutes, making an action plan and checking if appointed tasks have been accomplished; 7. are able to give an oral presentation of their results. They take care of a suitable form and substance of the presentation, of an appropriate use of audio-visual media and a satisfactory response to reactions from their audience.	*4. reflect on their experiences and lessons learned in international research collaboration and a new cultural environment*
BC learning activity (and/or assessment activity) in the course	*Excursion*: students cycle around Wageningen to visit different places and persons (municipality, NGO, involved inhabitant) related to the energy transition. Afterwards they are expected to reflect on the role and perspectives of stakeholders as well as their own. *Group assignment* to collaboratively: • develop a clear problem definition, highlighting the interrelated role of	*Lectures* by lecturers from different chair groups (social and natural sciences) sharing state of the art knowledge in their field of expertise and its relation to the central theme of the course. *Excursions* to various farms, a nature restoration project, and a representative of the regional government (province of Gelderland) to get a better insight in	Supervised *group research project* for a non-academic commissioner: writing a research proposal based on the problem as identified by the commissioner; collecting and analysing data; reporting orally and in writing. Collaborative *reflection on the societal context* of the research, to (i) explain the relationship with overarching environmental debates; (ii) clarify the societal context and impact of environmental research; (iii)	*Guest lectures* provided by experts from in- and outside the university, both in Wageningen and in Tartu/Kiev, to provide an introduction and state-of-the-art knowledge. Students are encouraged to prepare for these lectures and engage in discussions with the experts. *Practicals* to explore the study area and surroundings and learn

	technology, people, the environment, and various stakeholders. • analyze the problems in different ways, i.e., from the perspective of the natural sciences and the social sciences; • to develop a solution (synthesis); • reflect on the solution and its role in the energy transition; • report their findings in a group report and a presentation in a symposium. The group report assesses the student's ability to (a) collaboratively write a report on an interdisciplinary environmental problem on a specific scale (household, neighborhood, national, global); (b) develop a synthesis and solution using different types of sources; (c) reflect on the solution by referring to other scales and (d) work effectively in a team.	the environmental problems addressed in the course, and a better understanding of how the stakeholders deal with the various environmental problems. Students are expected to prepare questions with their group for the people they will meet prior to the visit. *Group assignment* "to provide an overview of the current and future environmental problems caused by the production and consumption of meat and to determine sustainable solutions whereby you take into account the interests, perspectives and considerations of the main stakeholders in the Animal Consumption and Production Chain" resulting in a written and oral report. *Training* on 'working in groups' and on 'giving an oral presentation'.	outline values and interests that may affect the methodology and outcomes of research; (iv) express a personal view on the problem studied and the interventions proposed to address this problem.	about ongoing research done by faculty members of the Estonian / Ukrainian University. *Intercultural competence training* to get insights in cultural differences. *Group assignment* aiming to: (1) carry out a joint research project/study, and (2) learn to collaborate in an intercultural team. Different nationalities and backgrounds are mixed to enhance the intercultural learning experience. *Reflection*: student have to reflect throughout the course on their own behaviour, attitude as well as actual steps taken to overcome challenges, and write a reflection assignment. Assessment is on both content (presentations and poster) and process (participation, engagement, and the reflection assignments).

		Orientation on study and job perspectives after graduation, followed by an individual assignment.		

Boundary Crossing Learning Trajectory BSc Food Technology



Course and its core theme	**Introduction to Food Technology** Learning to know the disciplinary and societal perspectives related to food technology (case 'Ready-to-Eat Salad')	**Food Properties and Function** Co-create a food innovation and take into account the consumer perspective	**Case Studies Product Quality** Study a case from industry and suggest product and process quality improvements	**BSc Thesis Food Technology** Food Tech research incl. report and presentation
What boundary / boundaries are addressed in the course?	Disciplinary University-Society Cultural	Disciplinary Cultural University-Society	Disciplinary University-Society	*The BSc thesis might be used for a final assessment of students' boundary crossing*

				competence development. We are discussing whether and how we will do this.
What BC learning mechanism are addressed? ○ Identification ○ Coordination ○ Reflection (perspective making /taking) ○ Transformation	• Identification (of disciplines, stakeholders, and cultures)	• Reflection (on consumer perceptions) • Transformation (co-creation of a food innovation)	• Coordination (communication with real life stakeholders) • Reflection (perspective making and taking on stakeholder assignment and perspectives)	
BC learning objectives of the course (italic, red objectives as part of the complete set of learning objectives)	*1. know and/or understand the basic elements and concepts of the scientific disciplines that span food technology;* 2. know the disciplinary frameworks that are constructed from the basic elements and concepts; 3. know and apply the knowledge on a defined set of basic phenomena to explain and control properties of foods, within the context of one discipline; 4. understand and apply this understanding how to manipulate these phenomena; *5. recognize which phenomena of different disciplines are relevant to explain and control properties of foods, and point out their interrelationship(s) (i.e. identify interdisciplinarity)*	*1. integrate theoretical and practical knowledge from various food science disciplines taking into account the consumer perspective as well;* 2. understand the implications of changes in food product ingredients or processing on the final product properties; 3. understand the effect of chosen processing on food properties and -quality; 4. understand how food quality can be determined with appropriate sensorial and instrumental approaches; 5. understand the methodology and use of modern analytical techniques; *6. understand the ethical issues involved in*	*1. apply basic knowledge from various disciplines in food technology to define and improve food product quality;* *2. translate a question from society (company, institute, start-up, government) into a feasible scientific research project;* 3. search, understand and use scientific literature; *4. work in a team on a joint research project, using inter- and intrapersonal skills* *5. communicate project progress with various stakeholders* 6. scientifically report and present project results	

	6. use ICT-software programs; 7. *have insight in the overall context in which the food industry and its stakeholders operate.*	*innovation of food products and to apply this knowledge in practical situations;* 7. work in small groups and to plan, carry out and evaluate experiments to make an innovated food product and to present the results.		
BC learning activity (and/or assessment activity) in the course	Students visit a company and get the assignment to prepare for a set of questions to be asked to the company staff on stakeholders involved, stakeholders' roles, perspectives and mutual relations, job opportunities etc. Students report their findings as part of the final assignment for the course (including a visualisation of the stakeholder analysis and reflection on suitability of various job positions, and how their view on job opportunities developed over time during the course). Lecture on intercultural communication, and related workshop on finding out intercultural perspectives on various topics.	As part of their innovation assignment, students investigate the consumer perception of their innovation in a broad sense (e.g. health; cultural; economic). They interview real life consumers, and apply consumer perceptions into their innovation. In their final reports, students are required to describe how the identified consumer perspectives have been used/applied in their innovations.	Real life commissioner introduces the case to the students. During the case study, students contact the commissioner and other stakeholders (identified by themselves) to discuss their progress and findings. Finally they present the results to the commissioner. Commissioner and stakeholders are stimulated to translate the findings into follow up assignments (for these or other students). Students write reflections, both mid-way and at the end on how they assessed the commissioners feedback and how they used the feedback in their further work.	

	Additional exam questions: which disciplines are integrated in the Ready-to-Eat Salad? Do you consider this set of disciplines to be complete? Why yes/no? Which other disciplines should actually be integrated?			

THE FIRST YEAR EXPERIENCE AS THE CONTEXT OF USE

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Conference Key Areas: *E-learning, blended learning, Virtual reality, Diversity and Inclusiveness*
Keywords: *Context of use, motivation, first year of study, LMS*

ABSTRACT

The Technical University of Denmark (DTU) is implementing a new Learning Management System (LMS). Successful scaffolding via an LMS requires in-depth knowledge about how students perceive and use the content and the system.

According to the *Situated Action*-approach, however, human activity and thinking is based on a "swarm of contingencies". Thus, nothing can be understood without first understanding its context (Button & Sharrock, 2009, p. 78).

This implies that careful design of content and flows in the LMS will fall short of supporting student learning, if teachers fail to understand the contingencies surrounding the students' use of the LMS, which might impair their focus and understanding.

In order to increase our knowledge of students' use of the LMS an initial qualitative study was carried out. In particular, the aim was to start exploring *the context of use*: The first year experience, motivation, work pressure, and coherence in order to see which aspects might influence the students' use of the LMS and their learning process.

This preliminary study did reveal that the students experience a significant amount of confusion and stress. Especially the overwhelming transition from being a high-school student to the more independent life of a university student seemed to take a toll on the students. This paper presents and discusses these findings and suggests how they will influence our further study and use of the LMS.

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1 INTRODUCTION

The Technical University of Denmark (DTU) is implementing a new Learning Management System (LMS). The chosen platform is Brightspace (D2L). The new LMS offers teachers many new possibilities. At the same time, it is a challenge to utilize these possibilities, since the teachers are not familiar with – and to some extent overwhelmed by – many of those new functions and possibilities.

The motivation for the study presented and discussed in this paper was a question of how best to scaffold the students' learning process via the LMS. There was a sense that not all students did access the course materials as intended. If the scaffolding provided via the content in the LMS does not actually reach the students there is a risk that student learning may be impaired. Hence, there was a desire to know more about how the students interact with the LMS and the content in order to understand the student experience.

The informants of this study is a cohort of first year students in the *Process and Innovation* bachelor of engineering programme at DTU. The new LMS is being used in most of the first year courses. One of the authors of this paper (K. From) teaches one of the courses, *Design, users, and ethics* (5 credits), in which the teaching method is primarily flipped classroom, hence increasing the importance of students using the course material as intended.

The initial study, however, did not focus specifically on the students' interaction with the LMS. Instead, the study took a more explorative approach in order to answer the following questions: Which *contingencies* influence the students' *first year experience* and use of the LMS and how do the students define the *context of use*?

One of these contingencies was assumed to be a heavy workload. In the fall of 2019 a total of 62 students were enrolled in the *Process and Innovation* bachelor of engineering programme at DTU. Only 33 respectively 28 students passed the exams in mathematics respectively physics at the end of their first term. In other words, only a bit above (53%) respectively a bit below (45%) half of the enrolled students passed the courses in mathematics and physics. The study was expected to shed some light on whether the workload was the cause of these low numbers.

2 METHODOLOGY

As mentioned above the focus for this study is the *contingencies* that influence the students' experience and the *context of use*. However, it is also a premise in this study that motivation is important to students' use of an LMS; the system is new to first year students and they have to learn how to use it – along with everything else they have to learn. Hence, Professor Vincent Tinto's model (explained below) of motivation and persistence (Tinto, 2017) is applied in the analysis in order to make an overall categorization and identify the relevant contingencies.

2.1 Situated action the context of use

The authors take inspiration from the field of *workplace studies* and the *situated action* approach (Button & Sharrock, 2009). Button & Sharrock argue that all work is *situated*. That is, it takes place within a *swarm of contingencies* (Button & Sharrock, 2009, p. 76). How people work is, in part, constituted in how they are handling these contingencies. According to Button and Sharrock, the nature of the context can be seen from how people are doing their work, and just how they are invoking context. In this study, we are exploring how the students in this way define the relevant context and the contingencies that influence the students' thinking and action.

2.2 Vincent Tinto's model of motivation and persistence

Professor Vincent Tinto (Tinto, 2017, p. 254-255) argues that universities should take the student perspective in order to understand what makes student persist and complete their studies – as opposed to dropout or retention, which usually is the focus of institutions.

According to Tinto, the key to persistence is motivation, which, in this context, can be strengthened or weakened by the three elements of *self-efficacy*, *sense of belonging* and *perception of curriculum* – as illustrated in Figure 1.

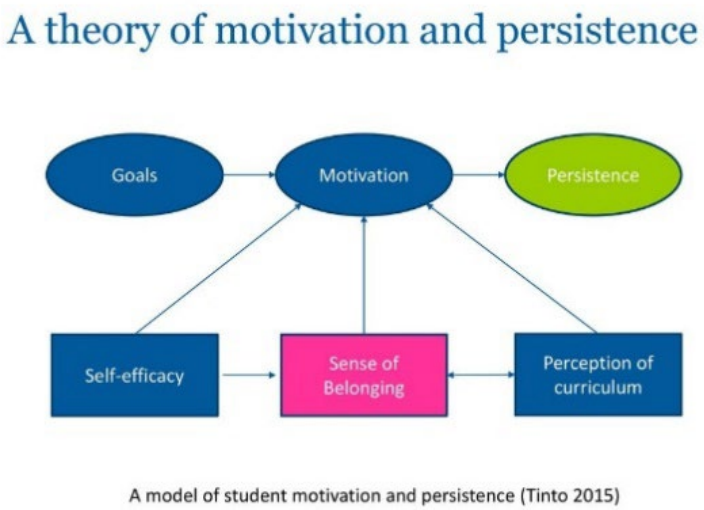

Figure 1: Vincent Tinto's model of motivation and persistence

Self-Efficacy
Self-efficacy can be defined as a person's belief in own ability to succeed in a specific situation or at a specific task. "Sense of self-efficacy influences, in turn, how a person addresses goals, tasks, and challenges. A strong sense of self-efficacy promotes goal attainment. Persons with high self-efficacy will engage more readily in a task, expend more effort, and persist longer in the completion of that task and do so even when they encounter difficulties. Conversely, a weak sense of self-efficacy tends to undermine achievement." (Tinto, 2017, p. 257).

Sense of belonging
Students' sense of belonging is shaped by the campus climate and the perceptions of belonging students form by their continuous interactions with fellow students, faculty, staff, and administrators on campus. "Students who perceive themselves as belonging are more likely to persist.[…] (Tinto, 2017, p. 258). By contrast, a student's sense of not belonging, of being out of place, leads to withdrawal from contact that further undermines motivation to persist." (Tinto, 2017, p. 258).

Perception of curriculum
Students' perception of the value and relevance of their studies also influence their motivation. Students' perceptions of the quality of the curriculum and its relevance are of key importance for student motivation. "Perceptions of the quality and relevance of the curriculum reflect a complex interplay among a variety of issues including faculty teaching methods, perceived institutional quality, and student learning style preferences and values." (Tinto, 2017, p. 259) Students must perceive that the material to be learned is of sufficient quality for them to spend their time and effort on. The learning tasks must make sense and be meaningful. Only then will students be motivated to engage in the learning tasks and persist. If students perceive the curriculum and/or learning tasks as unrewarding, irrelevant, or of low quality, their motivation will be weakened (Tinto, 2017, p. 259, Illeris, 1999, p. 174).

2.3 Method and research design

Two focus group interviews were carried out. One group with four students and another group with five students. The focus group is a qualitative method that allows researchers to produce data about the interpretations, interactions and norms of social groups in discussions facilitated by a moderator (Halkier, 2016, s.13).

This method does not produce results that are representative, but that is not the point either. In this study the aim was to begin to form an understanding of the student experience and to learn which questions would be relevant to ask in the next part of the study.

The themes students were interviewed about were:

1) Their study behavior, challenges, and habits
2) Their learning process and outcome and
3) Their use of resources (e.g., textbooks, video tutorials, lectures, group work, and material on the LMS) when studying

The recorded interviews were transcribed, anonymized and analyzed in accordance with Tinto's three categories of self-efficacy, sense of belonging, and perception of curriculum. Inspired by the aforementioned situated action approach, we furthermore analyzed how the participants oriented themselves toward their context. As the participants are enrolled in courses that one of the authors (K. From) is currently teaching, From did not participate in the focus group interviews as this might prevent the participants from speaking their mind about these courses. From did, however, participate in the analysis of the anonymized transcripts of the interviews.

3 RESULTS

3.1 Key findings

Our most significant empirical findings are:

- In general, the students' *self-efficacy* seems to be under pressure: Especially the workload and the difficulties of balancing work and life seem to be stressful for the students.

- The student seem to have a strong *sense of belonging*.
- The students' *perception of curriculum* seems to be negatively influenced by confusion about the meaning of several courses and how the courses in their programme are interconnected.
- For these first year students *the context of use* and relevant *contingencies* seems to include the aforementioned stress and confusion related to workload and studying. However, the transition from being a high school student living at home with mum and dad to being a university student living alone is stressful and difficult to handle. Workload, social life, cooking and doing the dishes – that is, *student life* in its whole, seems to be included in the *context of use.*

The findings are presented in more detail below. All quotes are translated from Danish.

3.2 Key findings: Self-efficacy

A general trend in the two groups are that the students are overwhelmed by the workload:

> ”It was a lot of things. There was the weekly mathematics home assignment, the weekly reflective report. There was a lot of theory to read in some of the courses. I had a really hard time structuring [everything]” (P1, #1 p. 8)

The following student has postponed a course:

> “[…] I did for example choose to postpone the mathematics course until next semester, because I didn't feel I had the time to do everything […] otherwise I would not make it to the end of the semester.” (P4, #1 p. 11)

One of the students is feeling the need for some advice:

> ”I would like to have someone teach me how to organize my time outside of class, because there's a huge difference between living at home and going to high school and living in a dorm and now having to cook, and study and do assignments, and then also having a social life” (P4, #1 p. 10)

Another student also talks about balancing studying and housework:

> ”When you finally have some time off you really want to relax but you can't, because you haven't done the dishes for a week, because you haven't had the time. It's your time off, but you are washing up, and then you need to sleep, because tomorrow you have to start all over again.” (P4, #2 p. 3)

Some of the students seemed to be very much affected by the amount of pressure:

> ”I was falling into a black whole [mentally] because of the amount of work. It's like you're bombarded from five different courses and social events, and you have to make it all work.” (P5, #1 p. 11)

Another student made a similar statement:

> ”I had a mental breakdown over the winter holiday, and when I had to go back, I thought ‘phew’!” (P2, #2 p. 22)

One student talks about the whole experience of the first year as being demotivating:

> "I just think it's a shame that the first year is so demotivating. I've talked to others that feel the same way. They feel demotivated by several courses because they can't keep up with everything. Maybe I'm lucky that I can force myself through things" (P4, #2 s. 4)

Notably, this student concludes that the whole of the first year is demotivating because of the workload.

3.3 Key findings: Sense of belonging

The participants in both focus groups seemed to have a strong sense of belonging. This student explain what it means to them:

> "It is super motivating to be part of a group of students so we don't have to study alone all the time. Taking classes with people you know make you more motivated and you have more friends to see". (P1, #1, p. 26)

Similar, another student said:

> " […] I don't know how I would get through university without a social network. It comforts me when I sit alone and read a text that I don't want to read, that someone else probably thinks it even worse than I do. And then I can go on reading for a bit longer". (P4, #1 p. 29)

3.4 Key findings: Perception of curriculum

In general, the students expressed confusion and doubt about the meaning of some of their first term courses. Furthermore, the students found it difficult to understand how the first term courses are connected to the other courses in their educational programme:

> "And I think it's the same with mathematics, when we graduate we are done with mathematics". (P1, #1, p. 17)

One of the students have learnt from an older student that part of the curriculum only is relevant to some engineering students in a different programme than theirs:

> "And he did actually say that things like complex numbers is something that electrical engineers use, but he had never needed it himself. […] That was demotivating, because that means I have to struggle with complex numbers and I'll never use them. That is just such a mega waste of time". (P1, #2, p.13)

This story seems to be indeed very demotivating for the students.

4 SUMMARY

The context and contingencies which the interviewed students orient themselves towards seem to include a heavy workload and severe difficulties balancing work and social life. For some students this leads to a "mental breakdown", falling "into a black hole", or the pressure makes them postpone one or more courses and exams. Furthermore, the pressure is a severe threat to their *self-efficacy*. In general, the interviewed students seems to be somewhat confused about the relevance of some of

their first term courses. Thus, the relevance of the mathematics course and specific – more theoretical and academic – topics seem to affect their *perception of curriculum* in a negative and demotivating way.

However, the students seem to have a very strong *sense of belonging* because of the social network they formed in their first year. This strong sense of belonging seems to motivate them and help them carry on and, hopefully, persist.

Although Vincent Tinto's model of motivation does not include the whole of student life – the interviewed students seem to orient and concern themselves towards cooking, doing dishes, and social activities in their spare time. Thus, it is necessary to consider these activities as part of the *context of use*, because these activities, and, in a broader sense, the transition from being a high-school student living at home with mum and dad to living alone and being a higher education student, seems to be of great importance for the students and for their (new) life.

5 FURTHER RESEARCH

It is important to consider the context of use in the next part of the study which will have a more narrow focus on the students' use of the LMS and the LMS' scaffolding nature with respect to student motivation and learning. It is well-known that stress can affect cognitive performance including memory (Sandi, 2013, 245) and a lack of motivation is also likely to affect the time and effort students will spend learning to use the LMS. If, however, there is a strong sense of belonging among these students, this may prove to be a resource that teachers can tap into – perhaps by enhancing social aspects of scaffolding via the LMS.

Obviously, two focus group interviews with a total of nine students cannot tell us if our results are, in fact, general trends. This was, however, never the point. Merely, the point was to identify relevant themes to investigate further in the next part of the study, and which relevant contingencies can be observed to influence the students' use of the LMS.

Thus, the following questions need to be explored further:

- Is it a general trend that the students in this educational programme feel overwhelmed and stressed about the workload?
- Is it a general trend that students in this educational programme have a negative perception of the meaning of parts of the curriculum?
- Is it a general trend that students in this educational programme have a strong sense of belonging?
- Is it a general trend that the *context of use* includes aspects of student life as a whole?
- If so, how do these trends influence the students' use of the LMS, and could a sense of belonging be a resource for teachers?

As well as the main question:

- In which ways does the LMS and the content scaffold the students' learning process?

The starting point for this study was a desire to use the new learning management system at DTU to scaffold and enhance student learning. This study has shown that students indeed seem to face a number of challenges as first year students in an educational programme at DTU. These observations will be valuable in further research on the learning of engineering students in order to develop the educational programme and the use of the LMS for scaffolding and support of the students in their transition from high-school pupils to students at DTU.

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REVISITING THE STUDENT OUTCOME "ETHICAL, ENVIRONMENTAL AND PROFESSIONAL RESPONSIBILITY" WITHIN THE CIVIL ENGINEERING BACHELOR DEGREE

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ABSTRACT

In 2013, an institutional project was launched at Universitat Politècnica de València to ensure that all graduates, in addition to acquiring the specific technological skills of their degrees, would also acquire a series of essential soft skills for developing their profession in an excellent way.

At present, there are already graduates who have completed the degree with the integration of generic outcomes; therefore, it is time to review the success that the project has achieved. One of these generic outcomes is "Ethical, environmental and professional responsibility". In this work, we develop a diagnosis of the current state of this competence in the civil engineering BSc degree programme, and we analyse the level of acquisition of the competence by students.

For this purpose, the subjects in which this generic competence is worked on and evaluated will be analysed, studying how lecturers introduce it within different activities to collect evidences of the competence level of acquisition. We also studied whether the results obtained respond to the expected learning goals.

The diagnosis will be completed by collecting opinions from last year students, as well as by interviewing lecturers responsible for these subjects.

The final objective of the project will be to estimate at what extent the students have acquired this competence upon graduation and to propose improvement measures if necessary.

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1 INTRODUCTION

1.1 The scenario at the Spanish University

At Spanish universities teaching civil engineering bachelor degrees, ethical training has never been of great importance from the point of view of the curriculum design. Traditionally, some of the schools offered elective subjects related to ethics, but in most of them, they were directly ignored [1].

However, with the implementation of the European Higher Education Area (EHEA) based on the Bologna Declaration, degrees offered by Spanish universities were revised and updated. One of the consequences of the adoption of EHEA was the division of students' learning into three categories [2]: knowledge, skills and competences. This new vision came out due to the need to provide students and future professionals with a comprehensive training that would qualify them to be excellent professionals, not only from a technical point of view, but also in a more holistic dimension.

In Spain, this fact was accompanied by the increase of universities teaching the bachelor degree in civil engineering [3]. This fact encouraged academic institutions to obtain national and international accreditations to demonstrate the quality of its graduates in comparison with other schools. The most recognised accreditations are EURACE® and ABET labels, and both mention the ethical behaviour of professionals as learning outcomes that students must obtain [4].

At this time, the need arose to incorporate ethical and professional responsibility into the curriculum. Universitat Politècnica de València (UPV) decided to launch an institutional programme [5] to integrate 13 generic outcomes into all degrees programmes, covering topics such as time management, effective communication, teamwork or ethical, environmental and professional responsibility.

1.2 Context-The UPV's Generic Outcomes project

The UPV's Generic Outcomes (GO) project began in 2013 and its main objective is to certify that all students have achieved them once graduated from any of the UPV bachelor degrees. Towards the end of the 2013-14 academic year, training activities were carried out in all the schools to prepare the project and to inform the management teams of the need to start carrying out pilot activities during the 2014-15 academic year. The project was definitively implemented during the 2015-16 academic year. The strategic plan of the UPV 2020 [6] includes the correct accreditation of the GO defined by the UPV.

In each programme, different subjects were established as control points for each proficiency level of each generic outcome. Two proficiency levels were established for each competence corresponding to bachelor´s studies, and a third proficiency level corresponding to master's studies. The subjects defined as control points must collect evidences of the proficiency level achieved by students in the GO.

The Institute of Education Sciences (ICE) of the UPV published a document entitled Generic Outcomes with support material for teachers [7]. It described the 13 GOs: GO1-Comprehension and Integration, GO2-Application and practical thinking, GO3-

Analysis and problem solving, GO4-Innovation, creativity and entrepreneurship, GO5-Design and project, GO6-Teamwork and leadership, GO7-Ethical, environmental and professional responsibility, GO8-Effective Communication, GO9-Critical thinking, GO10-Knowledge of contemporary problems, GO11-Lifelong Learning, GO12-Time planning and management, and GO13-Specific instruments.

The UPV quantifies the achievement level of the GOs of the graduates, providing a measure of their added value to give them a differentiating attraction compared to their competitors. In addition to describing the content of each competence, this document established the learning outcomes that students should achieve for each proficiency level, provided rubrics for evaluating them, and suggested different activities and techniques for working and evaluating the competence in the classroom. In addition to this document, the ICE offered training workshops, produced videos to disseminate the 13 generic outcomes and provided support to all teachers, especially those who were selected to be control points.

In the 2017-18 academic year, bachelor and master's students began to be certified as having completed all the proficiency levels corresponding to their studies and therefore UPV is now ready to check the state of achievement of the different GOs.

The generic outcomes at the UPV cover several aspects. Many of these aspects were already worked in the pre-Bologna curriculum, even though they were not specifically called "generic outcomes". Indeed, it seems impossible that engineers graduated before the implementation of the institutional project would be able to finish their studies without having competences in "comprehension and integration", "analysis and problem solving", or "design and project", for example. These outcomes are worked on in many subjects present in the civil engineering bachelor degree curriculum.

However, other learning outcomes are difficult to include in the curriculum in a transversal way. They need theoretical foundations that can hardly be contained in other specific subjects. This is the case of GO-7 Ethical, environmental and professional responsibility.And yet, as noted above, this competence is explicitly cited in the learning outcomes required by the most prestigious quality labels, which may account for its importance. It is therefore time to study and evaluate how this competence has been developed within the curriculum and whether the required learning outcomes are achieved.

2 METHODOLOGY

2.1 Objectives

The general objective of the work developed at the School of Civil Engineering is to study and carry out a diagnosis of the state of achievement of the generic outcome GO-7 "Ethical, environmental and professional responsibility", at each of the proficiency levels foreseen in the civil engineering bachelor degree studies at the UPV.

This diagnosis includes the review of the methodologies, activities, evidences and rubrics used, as well as the study of the suitability of the subjects selected as control points.
Based on this diagnosis, improvement actions will be studied that may range from improving institutional rubrics to adapt them to the context and to the development of training actions consistent with GO7. "Pilot" subjects will be established as control points, and in the 2020-21 academic year new activities will be introduced with new evidences and, if necessary, new rubrics to ensure the acquisition of this generic outcome by students at the end of their studies.
From the diagnosis, we can highlight the following aspects:

- The subjects in which students work on the generic outcome GO7 will be known, specifying whether they are compulsory (they must be taken by all the students).
- Evidence and evaluation methods for each proficiency level will be reviewed.
- The degree of complexity of the tasks will be analysed regarding the corresponding proficiency level.
- Activities will be designed and the institutional rubrics of each proficiency level of the competence will be reviewed.
- A vertical coordination will be established for all the control point subjects of GO7. In this way, activities to be carried out by students for the achievement of the learning outcome will be organized throughout the programme.
- Pilot subjects will be selected as control points.
- New activities and rubrics will be implemented.
- And finally, the action will be evaluated.

2.2 Method, tools and work plan

To obtain information about the activities and the evaluation method of this transversal competence, we have studied and analysed the course syllabus of the control point subjects and the competence report. This analysis was completed with personal interviews with lecturers responsible for these subjects. In addition, a performance of group dynamics with students in the last year of the degree was developed to collect their opinion and perceptions about the achievement of this competence.
In the future, we would like to extend the study to graduates with professional experience to collect their opinions about the training obtained during their degree studies in this field and their usefulness or perception of lack of training and need in the field of ethical and professional responsibility.
The work plan for the diagnosis of the state of GO7 "ethical, environmental and professional responsibility" in the civil engineering bachelor degree covers the duration of an academic year. Based on this diagnosis, some improvement actions are proposed to be implemented in the curriculum and later to evaluate the effectiveness of the proposals. The tasks of the work plan are:
Task 1: Review of the subjects that are currently control points of GO7, and collection of evidence of the achievement level.

Task 2: Analysis of the evidences and suitability to the proficiency levels of the competence achievement.
Task 3: Selection of the most appropriate subjects in the curriculum to be a control point for GO7.
Task 4: Design of new activities and suitability of rubrics for the control point subjects.
Task 5: Use of the new activities and rubrics in the control point Pilot subjects.
Task 6: Collection of evidence of competence achievement and analysis of assessment.
Task 7: Monitoring the evolution of the student achievement of the two proficiency levels required in the bachelor´s degree.

3 RESULTS

3.1 Analysis of syllabus

At the moment, there are five subjects defined in the curriculum as control point subjects of GO7 (see table 1).

Table 1. Control point subjects

Subject	Type	Year	ECTS	Proficiency level
Topography	Compulsory	2	4,5	1
Science and Environmental Impact of Civil Engineering	Compulsory	2	4,5	1
Industrialised construction	Compulsory	3	4,5	2
Construction Management and Organization	Elective	4	4,5	2
Ethics in Civil Engineering	Elective	4	4,5	2

By analysing their content, it can be concluded:

- All subjects adapt the difficulty of the GO7 activity to the difficulty of the course.
- No subject uses institutional rubrics to carry out the assessment.
- Among the assessment methods presented, simplified rubrics and Likert scale questionnaires are used.
- Most of the activities are contextualised into the specific subject.
- It is not evident that the proposed activities in each subject will let students to achieve the proficiency level desired for the generic outcome.
- The fourth-year subjects in which this GO is introduced are elective, so it is not certain that all students will take them.

3.2 Group dynamics with final year students

A group dynamic was proposed with final year students who had already taken all the control point subjects of the GO7, to find out their opinion on how they achieved the competence and they were evaluated. A 90-minute session was conducted, in which the students were very proactive and enthusiastic to communicate their impressions.

In this session, future engineers were also asked about which curriculum subjects they consider most appropriate to incorporate this transversal competence.
The students were quite dissatisfied with the way this learning outcome was introduced and among the criticisms expressed, we highlight the following:

- In some of the control point subjects, they do not remember doing any activity related to GO7.
- They think that the activities are not well related to the proficiency level to be achieved, and show disagreement with being assessed for a competence for which they have not been trained.
- They are dissatisfied with being, in some cases, evaluated for a GO, in this case ethical, environmental and professional responsibility, of which they are not aware that they are working and being evaluated.
- Less than 2% of the students believe that they have fully achieved the competence with the activities carried out in the control point subjects.

A part of the group dynamic was reserved to ask the students their opinion about the best way to introduce this learning outcome in the classroom, and among the most frequent proposals, we can mention:

- Spending time in classroom to reflect on the GOs, discussing how to teach and evaluate these competences. They want to be active actors and to express their opinion about their needs as professionals.
- Providing students material related to the generic outcome and applications to real cases.
- Involving the academic staff (their attitude is not always optimal) in order they feel motivated to work and evaluate this competence.
- To train lecturers who will be in charge of working and evaluating this generic outcome.

Finally, the most frequent request of the students was to turn the competence into a compulsory subject "Ethics in Civil Engineering".
As for the compulsory subjects that students consider more appropriate to introduce this learning outcome in a transverse way, “Science and Environmental Impact of Civil Engineering” and “Construction Procedures” are the more suitable for proficiency level 1. In proficiency level 2, the only compulsory subject they consider able to work the topic is “Prevention of Occupational Risks and Work Organization”.

3.3 Interviews with academic staff

From the interviews conducted with academic staff, we would like to emphasize that all the lecturers interviewed think that this GO is essential for the complete professional development of civil engineers.
Another aspect to be highlighted is the different perception among students and lecturers of how the learning outcome is introduced in the classroom. For half of the lecturers it has been very easy to introduce the competence as a transversal content

for their specific subject, but the students have not noticed that this competence is worked on.
On the other hand, they have mainly answered that they have never been trained to teach GOs. Indeed, the training offered by the ICE is not compulsory, so they would not have been able to attend or would have considered it unnecessary.
It is interesting to note that even among lecturers responsible for integrating and evaluating this generic outcome in their specific subjects (all engineers), there is a small part who consider that they do not need training (because we all have our ethics, right, or we are engineers then we are virtuous). These opinions clash head-on with the fact that ethics is a type of knowledge that seeks to guide human action in a racial sense [8] and, being a type of knowledge, it can be taught, beyond knowing the deontological codes of a profession. Fortunately, most of the lecturers interviewed call for training or think that this type of content should be given by people trained for it, recognizing and manifesting their limitations in order to carry out the task that has been entrusted to them.

4 CONCLUSION

Let's remember that the general objective of this work is to study and carry out a diagnosis of the state of achievement of the generic outcome GO7 "Ethical, environmental and professional responsibility", at each of the proficiency levels foreseen in the civil engineering bachelor degree at the UPV.
After the review of all the material, the group dynamics with students and the interviews with professors, it can be concluded:

- In general, not enough evidences have been collected to fully certify that the students of the Civil Engineering bachelor degree have achieved the required proficiency level in this GO, at the end of their studies.
- The institutional rubrics for evaluating GO7 may be too complex and even confusing. This may have contributed to the fact that they are not used in the subjects analysed so far.
- It is necessary to correctly explain to students the purpose of the GOs, to name those that are worked on in each of the specific subjects (especially if they are to be evaluated), and to give competency-related training before assessing whether the students have reached the desired level of domain. Students want to learn.
- For the success of the project, the collaboration of the academic staff responsible for the control point subjects is essential.
- This generic outcome is difficult to work with and evaluate, so all possible help and collaboration must be provided to lecturers involved.
- And, maybe, this is not the best way (like generic competence) to introduce ethical and professional responsibility into the Civil Engineering bachelor degree.

We think that this is an essential learning outcome to be able to develop any profession in an excellent way. This opinion is supported by the fact that international agencies that accredit the quality of different university studies, such as ABET, have among the seven learning outcomes that students should have at the end of their university studies "the ability to recognize ethical and professional responsibilities in engineering situations and to make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and social contexts".
After the discussions with the agents involved, the results obtained and the social demand, there are strong reasons to consider a compulsory subject in the curriculum oriented to help future engineers to develop their professional activity with the necessary responsibility and ethics.

5 ACKNOWLEDGMENTS

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ENGAGING SOFTWARE ENGINEERING STUDENTS IN GRADING

The effects of peer assessment on self-evaluation, motivation, and study time

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ABSTRACT

Peer assessment is a popular technique for a more fine-grained evaluation of individual students in group projects. Its effect on the evaluation is well studied. However, its effects on the learning abilities of students are often overlooked. In this paper, we explore self-evaluation, motivation, and study time of students in relation to peer assessment, as part of an ongoing project at our local Faculty of Engineering Technology. The aggregated measurements of two years so far show that: (1) students get much better at evaluating their own project on some, but not all, of the evaluation criteria after a peer assessment session, (2) students report in a follow-up survey that they are more motivated to work on their project, and (3) the relation between motivation and time spent on the project increases. These results suggest that peer grading could have positive long-term effects on the reflective, and therefore lifelong learning, skills of students. A better understanding of the evaluation criteria results in more accurate self and peer grades, emphasizing the importance of properly defining and communicating these criteria throughout the semester.

1. INTRODUCTION

Engineering students are faced with the challenging task of gaining technical knowledge in their specific field to be able to graduate and hopefully cope with future professional environments in the industry. However, technical expertise does not suffice: several non-technical skills such as self-reflection, lifelong learning, creativity, and empathy are also expected of freshly graduated engineers, whether it is in the field of software engineering [1] or in any other engineering field [2].

In order to enhance the learning of these non-technical skills, without making any compromises to the gaining of technical knowledge, we propose the introduction of peer assessment. Peer assessment has often been used to enhance exactly these skills [3,4]. The development of self-evaluative skills and the awareness that lifelong learning is a necessity for an engineer are our main goals. We are therefore interested in the following research questions, for which there is currently only sporadic evidence:

- **Q1**: *What are the effects of peer assessment on self-evaluation?*
- **Q2**: *What are the effects of peer assessment on motivation and study time?*

The remainder of this paper is divided into the following sections. Section 2 describes background information and related work on peer assessment, and why it is of growing importance. Section 3 clarifies the process we have followed to collect data of two years. Next, in Section 4 we present and discuss our findings. Possible limitations are identified in Section 5, while Section 6 concludes this work.

2. BACKGROUND AND RELATED WORK

As stated by Sitthiworachart and Joy, "*The use of peer assessment is claimed to enhance students' evaluative capacities, which improve the quality of their subsequent work*" [5]. Several papers, even from more than 20 years ago, argued that using self and peer assessment increases the students learning capabilities [4]. Peer assessment is indeed "*as much about learning as assessment*" [5]. However, many papers lack a good body of empirical data to back up these claims, except for qualitative surveys and self-reports.

It is important to note that in the context of this work, we are in not focusing on the validity of peer assessment as a tool to completely replace the grading of teachers. According to Sajjadi et al., intricate models that would correct any bias or variance in students' grading seems to be rather ineffective [6]. Researchers do not completely agree on the validity of peer grading: some find it to be adequate [7,8], while others find it very variable [9,10]. As our intention is to introduce peer assessment primarily as a learning tool for students, teacher assessment was not completely removed. Section 3 explains this grading system in greater detail.

3. METHODOLOGY

In a 'Software Design in C++' course for third year bachelor students Electronics/ICT at our local Faculty of Engineering Technology, we asked students to grade themselves, fill in a follow-up survey on motivation, and to keep track of their study time on the project of the course. In the second academic year, peer assessment was introduced.

The first academic year, 2018-19 (N = 25 students), served as a baseline, while the introduction of peer assessment in the second academic year, 2019-20 (N = 27 students), served as the study group. As part of the evaluation process for this course, students are required to complete an integrated assignment presented as a project, which accounts for 50% of the total score (divided into 27% peer grades, 23% teacher grades). Project assignments are very open-ended: students can choose to implement anything they like, as long as the following requirements are met:

- The target programming language is C++11, and the target platform is the Game Boy Advance. Naturally, every student opts for the creation of some kind of 2D game.
- A GBA sprite engine was custom built for this course to reduce the technical challenges of working with a low-level embedded hardware system such as the GBA [11]. Students were required to start from this engine.

An evaluation rubric was adopted from [10] to make both the self and peer evaluation process easier for students. This rubric was also employed by the teaching staff in both academic years. Since the Software Design course is a programming course, different

non-technical and technical criteria were needed to evaluate different aspects of student projects. Table 1 summarizes this rubric and provides examples of low and high scores. Cardinal rating was employed by providing a score for each criterion between `0` to `5`, after which weights are assigned and a global score on `20` is calculated.

Table 1: The qualitative evaluation rubric used to grade the projects.

Weight	Criteria	Examples
`0.4`	**Code Design**	*How well-designed is the project code?* High score: clearly recognizable objects, represented in domain model, separation of concerns. Low score: All code in single object, unclear what does what, barely or no model.
`0.5`	**Clean Code**	*How readable is the project code?* High score: use of understandable variables, methods, classes. Low score: Too much re-reading is needed to see what is happening.
`0.4`	**Complexity**	*How difficult was the project made?* High score: chosen for a challenge instead of a simple implementation. Low score: path with smallest resistance taken, the bar set too low.
`0.3`	**Creativity**	*How original and creative is the project idea?* High score: implemented an original idea instead of a clone of a default 2D platformer. Low score: opted for a less inspiring design, everything is based on existing work
`0.2`	**GBA UI**	*How elaborate is the presentation of the game?* High score: All UI/Sound techniques applied well: sprites, scrolling BG, … Low score: little to no animation/backgrounds, monotonous design.

This rubric is a condensed subset of the learning outcomes of the course. The rubric was made public in the very first lesson so that students could take this into account during the development of their project. Students were encouraged to work together in small groups to further reduce the complexity and stress of cross-compiling for the GBA. Therefore, the rubric was used to individually assess *projects* (and thus, a *group*).

Peer assessment was obligatory and took place a day after the submission deadline. Every group had exactly five minutes to demonstrate their project to their fellow students and the teaching staff. We recommended students to spend at least two minutes explaining the overall structure of the code, since two criteria are technical and evaluate the code quality. After the peer assessments, students were asked to individually evaluate their own project using the very same rubric.

To measure accuracy and motivation, a short follow-up survey was filled in after the self-assessment assignment, in which students had to answer the following questions:

1. How easy was it for you to evaluate yourself? (Likert scale, 1-5)
2. How accurate do you think your evaluation is? (Likert scale, 1-5)
3. How motivated were you while working on the project? (Likert scale, 1-5)
4. What motivated you? (Open-ended question)
5. What demotivated you? (Open-ended question)

To measure study time, students were required to keep track of the amount of time spent on working on the project. A template `csv` file was provided for them to fill in, noting the date and the number of hours spent working on the project that day. A simple `csv` file was used to reduce the administrative load as much as possible, while still maintaining a high accuracy rate. A data correction step was necessary as many students made mistakes in noting the year (1018 instead of 2018, 2018 instead of 2019 in January, …).

Data was not collected anonymously since we wanted to compare self-grading with the actual grading marks. However, since the authors are also the teachers of the course, the data was made anonymous during the analysis of this research to prevent any bias that result from knowing student names.

4. RESULTS AND DISCUSSION

The collected data from two years was analyzed to help us estimate the effects of peer assessment on multiple variables. We will discuss the results based on the two research questions from Section 1.

Q1 - The effects of peer assessment on self-evaluation

To assess the accuracy of self-evaluation, as done in [10], correlations between self and teacher assessment were investigated and shown in Table 2 and in Figure 1. The Pearson correlation coefficient was calculated using the individual grades as elaborated in Section 3. Creativity was added to the evaluation rubric in the second year.

Table 2: Comparison of self (Stu.) and teacher assessment (Tea.): mean, standard deviation, and correlation values for each criterion in the evaluation rubric.

		Design		Clean Code		Complexity		UI		Creativity	
		Stu.	Tea.	Stu.	Tea.	Stu.	Tea.	Stu.	Tea.	Stu.	Tea.
Year 1	Mean	3.17	3.71	3.54	3.08	3.13	3.04	3.21	3.50	/	/
	s.d.	1.010	1.197	0.658	0.881	0.850	1.233	1.062	1.142	/	/
	Corr.	**0.331**		**-0.231**		**0.202**		**0.376**		/	
Year 2	Mean	4.10	3.33	3.98	3.00	4.13	2.96	2.67	3.19	3,67	3.31
	s.d.	0.775	0.582	0.608	1.158	0.558	1.523	0.836	1.184	0.679	0.664
	Corr.	**0.105**		**0.341**		**0.666**		**0.713**		**0.528**	

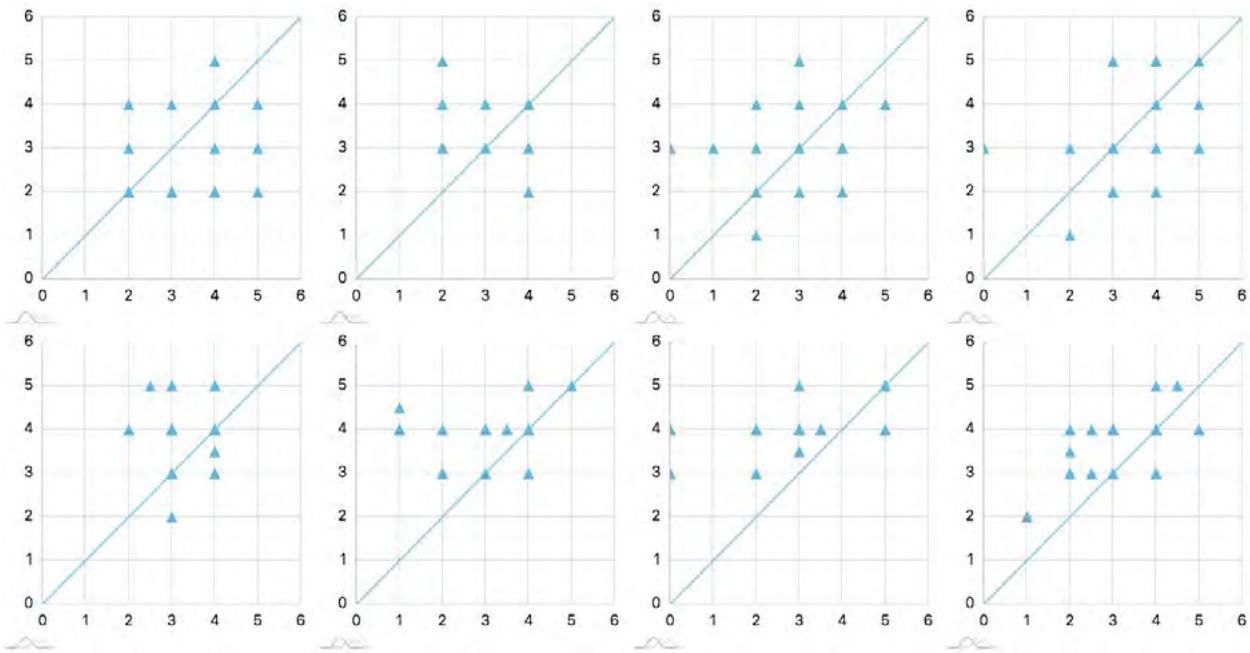

Figure 1: Scatter plots of self-evaluation (Y-axis) related to teacher-evaluation (X-axis) for each criterion. The closer to the centerline, the higher the correlation and the better the student's estimate. Left to right: Design, Clean Code, Complexity, UI. (Above: year 1. Below: year 2.)

When comparing the means between different years, we can clearly see that students who participated in peer grading generally graded themselves higher. This bias towards higher student gradings, as reported by other researchers [10], is also visible in Figure 1, where triangles evolve towards the left side of the centerline. Furthermore, as the correlation increases, the deviation decreases, revealing a higher level of agreement among the scores given by different students to the same project.

Students in the second year report that they found it easier to self-evaluate. Means from the Likert scales (1-5) are displayed in Table 3. This could signify that students get more comfortable evaluating projects during the peer grading process.

Table 3: Self-reported means for ease of grading and accuracy. 1 (hard/inaccurate) - 5 (easy/accurate).

Year	How easy to grade?	How accurate? (reported)
2018-19	3.25 (*s.d.* 1.073)	3.25 (*s.d.* 0.608)
2019-20	3.42 (*s.d.* 0.758)	3.62 (*s.d.* 0.571)

Evaluating *Design* and *Clean Code*

Students reported in the follow-up survey that it was very hard for them to objectively evaluate the criteria '*Design*' and '*Clean Code*'. One needs a firm grasp of programming techniques and a lot of experience in reading and evaluating code to be able to make a correct judgment. A few lab sessions are effectively dedicated to introducing students to these concepts. However, as they are still inexperienced, it is indeed very difficult to make a good estimate - especially within the a short time-frame of the presentation. No code was assessed in advance.

There is no strong relation between self and teacher grading in *Design* (`0.331` to `0.105`). However, the negative correlation in *Clean Code* evolves into a weak relation (`-0.231` to `0.341`), indicating that students at least have some idea on what is 'clean' and what is

not, after they have seen more code examples from their peers. This is an important lesson for us, as in the coming years more examples should be introduced in the labs, where room for discussions can lead to a better understanding of the concept.

Since the evaluation of both technical criteria relies on the assessment of source code text, other assessment methods such as comparative judgement could further increase the reliability of self and peer grades, as discovered by Goossens and De Maeyer [12].

Evaluating *Complexity* and *UI*

A strong increase in the correlation between self and teacher grading was registered for both *Complexity* (`0.202` to `0.666`) and *UI* (`0.376` to `0.713`), as also visible in Figure 1. The more examples students see and have to grade, the better they can estimate their own project on these criteria. Both *Complexity* and *UI* can be graded by looking at the end product (the GBA game) rather than the source code (C++ files). It is easier to evaluate whether your own game is less or more complex than others if you saw what your peers made. The same holds true for *UI*, where the biggest correlation was noted.

Students frequently applauded others for their ingenuity and resourcefulness. For example, multiple students were asking technical questions on how a group implemented dynamic background switching of their 'Mr. Driller' game. Students got inspired by taking a look at the work of others. However, the group presentation influenced the way the students do the assessment. The correlations could indicate that an introspective process was triggered that benefits the learning process of students.

Evaluating *Creativity*

Every year, students report that the single biggest motivator for them is the possibility to be creative with the GBA. Therefore, the *Creativity* criterion was added during the second year. No comparisons can be made. However, a weak correlation was registered after the peer grading process (`0.528`). The problem with creativity is that it can be interpreted in multiple ways, even if examples of good and bad grades have been provided in the rubric.

We are positive that this correlation can be easily increased provided that a clear definition of creativity is given. The projects are only one dimension of the 4P Creativity Model: the Product [13]. The Process dimension is something we already touch upon in the labs by introducing creative techniques to cope with the hardware limitations of the older GBA system. Our aim for the future is to better educate students on what it means to be creative. We are convinced that peer assessment can play a big role in the creativity of students, as also noted by Papaleontiou et al. [14]:

> *[…] As a guide for creativity, in order to promote creativity as product, with a view at the practical site of teaching, teachers should: […] encourage self and peer assessment and evaluation.*

Q2 - The effects of peer assessment on motivation and study time

Self-reported motivation

Students report a mean motivation of `3.58` (*s.d.* `0.659`) in year 1, and of `3.96` (*s.d.* `0.774`) in year 2. It is hard to say that this increase in motivation is due to the introduction of peer grading alone. Therefore, we also asked students to write down their motivators and demotivators, of which a selection of the answers is presented in Table 4.

Table 4: A sample of the reported motivators and demotivators for the GBA project of the course, throughout both academic years.

Stud.	Motivator (+)	Demotivator (-)
1	Creating something out of nothing	Things that did not work on the first few tries such as backgrounds and pointers
2	Great freedom to choose what is made	reverse engineering the GBA hardware
3	Passing the course	GBA memory issues
4	Using own inspiration, open nature of the project	no debugging
5	Creating a game, gaming to test it	Background difficulties
6	Being creative and looking for solutions	Bugs
7	GBA Nostalgia	Exams
8	It is something else than a default assignment	Limited memory capabilities, complexity
9	Seeing graphical progress when developing the game	Too much new concepts to learn

It is interesting to see that none of the students actually mentioned the peer evaluation process itself. However, that does not mean that their motivation was not influenced by the introduction of it. A classic mix of intrinsic ('*fun*') and extrinsic ('*good grades*') motivation was reported, as expected, with a clear bias towards intrinsic motivation. Of course, the fact that one could program on a gaming hardware device is one of the biggest reasons to be highly motivated. The main demotivators are related to the technical challenges of the project assignment.

Study time measurement breakdown

Figure 2 visualizes the total invested time per day for all students during the given academic years, divided into three parts. The biggest peak in the first part, mid December, is the last lab where students are allowed to work freely on their project. Most small dips are Sundays. During the second part, the Christmas holiday period, students clearly start worrying about their project and gradually invest more time. In the third part, a race towards the submission deadline begins, ending with almost 100 collective hours on a single day, averaging on 4 hours per student.

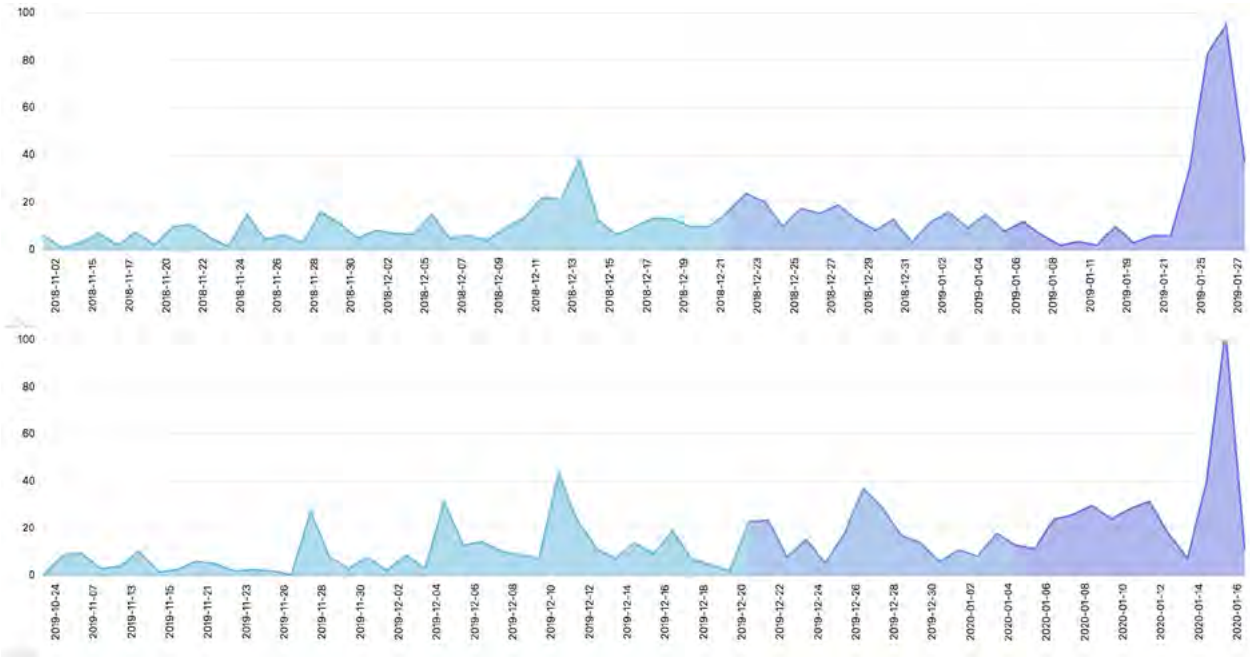

Figure 2: A normalized time graph of total invested hours, broken down in three color-coded parts: before Christmas break, Christmas break, before deadline. (Above: year 2018-19. Below: year 2019-20.)

No significant change in workload visible between the two years, except for the overall increase in the last race for the deadline. However, the average amount of hours decreases slightly, being 39.63 (*s.d.* 18.999) in the first year and 36.61 (*s.d.* 18.892) in the second. This leads us to conclude that having to evaluate fellow students does not drastically change the way students take on a project in general. They might overly rely on the good-will of others to give high grades. The usage of the peer evaluation system was stressed multiple times throughout the semester to make sure students remember how the evaluation of the course works, with a small negative effect on study time.

Link between motivation and study time

Table 5 and 6 display the correlation matrices for dependent variables time spent, motivation, and total grade. We suspected that motivation and study time investment would be closely linked together. However, without peer grading, no relation could be determined between time spent and motivation. The raw data reveals students with high grades that made little investment into the project, and students with low grades that made big investments. Averages on total grades are 13.73 for year 2018-19, and 13.29 for year 2019-20.

Table 5: Correlation matrix for year 2018-19

	Time spent	Motivation	Grade
Time Spent	-		
Motivation	**0.005**	-	
Total Grade	**0.394**	**-0.367**	-

Table 6: Correlation matrix for year 2019-20

	Time spent	Motivation	Grade
Time Spent	-		
Motivation	**0.331**	-	
Total Grade	**0.292**	**0.423**	-

No strong association could be derived with a correlation higher than 0.5. However, note again the big increase in correlations on motivation linked to time spent and total grade.

Coupled with the fact that student's self-reported motivation increases overall, the higher correlation suggests that the peer evaluation caused at least the motivated students to invest more time in the project. In a study carried out by Krapp [15], the distinction was made between intrinsic motivation called interest, and extrinsic motivation. Krapp discovered, as one would expect, that interest is more highly related to study time than extrinsic motivation. Our follow-up survey reveals the presence of both motivator types, which makes it harder get a distinct correlation.

5. LIMITATIONS

The biggest threat to the validity of this research is the limited scale of execution. It is not the student group size that is a concern, but the longitude of the research. As we measured only two years to date, more years could mitigate possible shortcomings in our study. However, the strongly deviating correlations presented in Section 4 are enough to substantiate the results. Existing research further supports this. Our intention is to continue with the data collection and the peer grading process in the coming years.

The peer evaluation process itself required students to fill in a form on paper. It is not impossible for students to copy grades of their neighbors while assigning a grade. However, this possible bias and/or variance was mitigated by still taking teacher grades into account. We did not aim for perfect peer grades, but rather for the positive effects of the grading process itself. Extreme positive biases, for example bulk grading or complete random grading, were not encountered. As students could already be motivated for this course, ceiling effects could have occurred on the motivational gains.

6. CONCLUSION

Peer assessment drastically improves the quality of self-assessment. Gracias and Garcia ask '*Can we trust peer grading?*' and conclude with mixed results [10]. We would like to change the question to '*Can we trust the positive effects of peer grading?*'. The answer is undoubtedly yes. Students are more motivated and can better evaluate their own work, even if there is no bigger quantifiable time investment measured. In contrast to a report by Sherrard et al. [16], our students did not express any reservations regarding the fairness of the peer grading system. Perhaps this is because teacher grades are still taken into account.

Future work involves examining how peer assessment can help with the development of engineering skills. The combination of peer assessment and creativity deserves special attention. After seeing the time investment interval from Figure 2, we also ask ourselves how to distribute this more proportionally. For instance, earlier and more frequent feedback during the development of the projects could help.

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BUILDING BRIDGES BETWEEN TECHNOLOGY AND MEDICINE: DESIGN AND EVALUATION OF THE TECHNICAL MEDICINE CURRICULUM

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Conference Key Areas: *Please select two Conference Key Topics*
Keywords: *curriculum design; curriculum evaluation; quality of patient care; innovation; medical technology*

ABSTRACT

Background. Technology takes an increasingly central role in healthcare. Rapid technological developments, complex problems and a labour market shortage requires healthcare professionals who can adapt successfully to these changes. Healthcare professionals using medical technology can no longer rely on monodisciplinary knowledge and skills. Therefore, a curriculum was developed to educate a new healthcare professional who can translate medical technology use into improved patient-specific procedures, the Technical Physician.
Objective. Qualitative analysis of the curriculum design, curriculum effectiveness and impact on Technical Physicians' practice in relation to quality of direct patient care.
Methodology. An educational design model was followed. Cognitive integration, self-directed learning, and technical-medical design projects were selected as main instructional principles. The impact of the curriculum was evaluated by 1) internal evaluation and accreditation reports and 2) semi-structured interviews with 30 alumni about the impact of Technical Physicians' practice on quality of direct patient care.
Results. The internal evaluation and accreditation reports showed that changes in the curriculum were required to ensure adaptive expertise development, enhance reflection and support continuing faculty development. Preliminary analysis of the interviews showed that alumni reported increased patient safety and more efficient and effective implementation of technology.
Discussion. Technical Physicians report that they are able to translate and use technology for safe, efficient and effective solutions for patient-specific problems in

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direct patient care. An important question that remains to be answered is whether our theory-inspired instructional principles result in adaptive expertise development in practice.

1 INTRODUCTION

Medical technologies are prominent in the top 10 most important innovations in medicine, according to a 2001 study by Fuchs and Sox [1]. A recent study by Aarts et al. [2] showed that physicians working in a high-tech clinical environment anticipated a further increase of technology use in healthcare. However, healthcare organizations and professionals are still often insufficiently aware of the risks associated with medical technology use [3,4]. Inappropriate use of medical technology by healthcare professionals who are unskilled but unaware of it leads to inefficient health care at best, or adverse events at worst [3,4]. The increasingly crucial role of technology in healthcare, combined with complex challenges and a labour market shortage, requires healthcare professionals who can adapt successfully to these changes [5].

1.1 Technical medical expertise

Healthcare professionals using medical technology can no longer rely on monodisciplinary knowledge and skills [6]. The challenges that healthcare professionals encounter when applying new technology or existing technology in a novel way are fundamentally different from the traditional diagnostic problems they were trained to tackle [7]. These problems where technology is used to innovate healthcare can be characterised as design problems [8]. Solving design problem requires conceptual knowledge, i.e. understanding the underlying principles used, knowing the functional requirements and knowing *why*. Also, for successful technology use with a specific patient, healthcare professionals need to be able to assess the consequences of the interaction between technology and the human body. These patient-specific, technological solutions should therefore be provided by professionals specifically trained to do so. A new healthcare professional is needed with specific technical-medical expertise to translate medical technology use into improved patient-specific procedures. These developments have led to the start of a new healthcare profession, the Technical Physician. As De Haan et al. [9] stated, it was assumed that the introduction of Technical Physicians in healthcare would increase the overall effectiveness and efficiency of direct patient care when using technology in innovative ways.

This concept paper reports on the qualitative findings regarding a) the design of a curriculum for Technical Physicians (TPs), b) curriculum effectiveness and c) perceived impact of the curriculum on TPs' practice in relation to the quality of direct patient care.

2 METHODOLOGY

2.1 Study setting and curriculum design

The curriculum was developed in The Netherlands at the University of Twente and implemented in 2003 (see Groenier et al. [10] for a more detailed description of the curriculum). A common and generic educational design model was followed [11]. Author HM was responsible for the design of the curriculum. A needs assessment was performed consisting of a literature review and interviews. Adaptive expertise theory [12] and research-based design [13] form the foundation of the professional profile. Three instructional principles were derived from the literature: cognitive integration to stimulate conceptual understanding and knowing *why* (cf. Lisk et al. [14]), self-directed learning to support students in developing their competencies (cf. Birney et al.[15]) and technical-medical design projects to practice solving complex, authentic technical-medical problems (cf. Carbonell et al. [16]). The content and core competencies of the curriculum were derived from the interviews with subject matter experts from various disciplines (e.g., physics, electrotechnical engineering, pathology, internal medicine, psychology). The curriculum spans six years: three undergraduate years and three graduate years, see Figure 1.

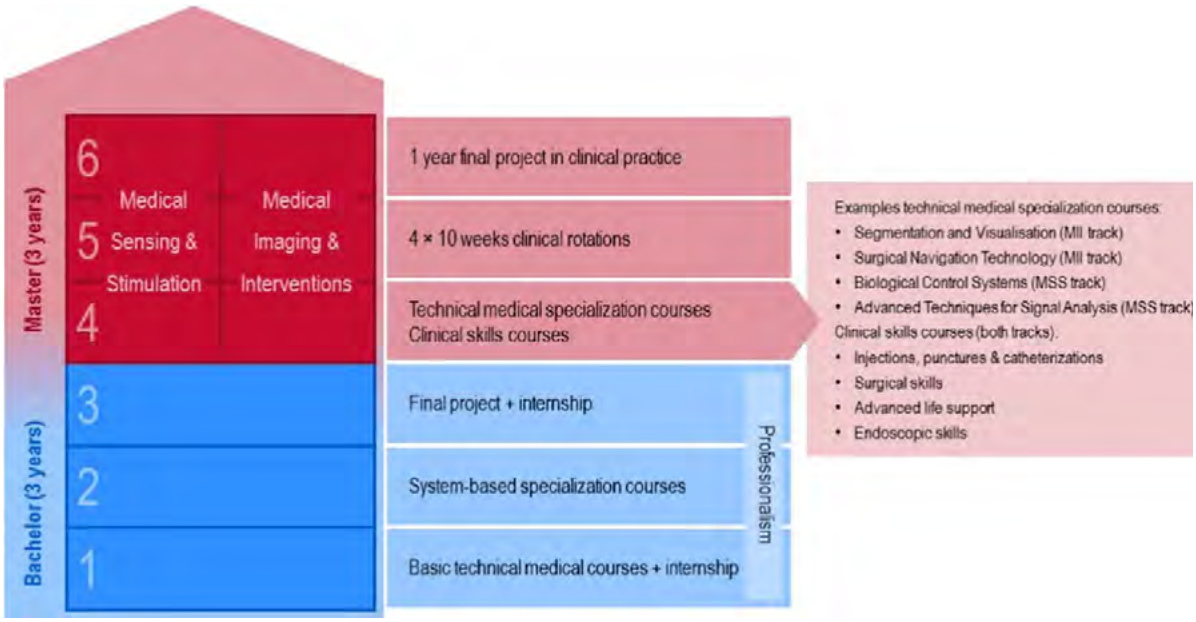

Fig. 1. Structure of the six year Technical Medicine curriculum (from Groenier et al., 2017)

2.2 Curriculum evaluation

Curriculum effectiveness was evaluated by examining internal evaluations and accreditation reports of the first years after the start of the curriculum in 2003. The perceived impact of the curriculum on TPs' practice in relation to quality of direct patient care was evaluated with semi-structured interviews with alumni of the Technical Medicine educational program.

2.2.1 Data collection interviews

Semi-structured, in-depth interviews were conducted in 2017-2018 with 30 TPs to explore the role and impact of TPs in healthcare. Practicing TPs were contacted through the Technical Medicine program of the University of Twente and the Dutch Association for Technical Medicine (NVvTG). The interview questions consisted of pre-structured and open-ended questions. They were divided into three sub-categories: daily work, impact indicators and additional comments. Impact indicators of TPs' practice on quality of direct patient care were: efficiency and effectiveness, safety, innovation and task shifting. Efficiency was defined as the degree to which actions of the Technical Physician resulted in reduced use of resources, e.g., equipment or staff, time to perform a medical intervention or time spent in the hospital, e.g., fewer visits to the hospital per patient. Effectiveness was defined as the degree to which actions of the Technical Physician resulted in more accurate, targeted or comfortable patient care, e.g., regarding diagnosis or treatment. Innovation was broadly defined as all actions of a Technical Physician that resulted in a new idea for improving patient care. Safety was also broadly defined as all actions of a Technical Physician that affected patient safety. All questions were constructed in consultation with a senior Health Sciences researcher. Six research assistants conducted the interviews, in person or by video call and all interviews were audio-recorded.

2.3 Data analysis

All available internal evaluations and accreditation reports of the early years of the curriculum were reviewed and summarized by HM. Recurring themes were extracted from the reports.

Each interview was reviewed by a different pair of research assistants. The first research assistant created a list of keywords mentioned by the interviewee for each impact indicator. The second research assistant reviewed the work of the first and revised the keywords if necessary. Next, the keywords were categorized into broader themes by three of the research assistants for each impact indicator across all interviewees. In case of disagreements between the research assistants, the differences were discussed until consensus was reached. The analysis resulted in a set of keywords for each category for each of the impact indicators.

3 RESULTS

3.1 Internal evaluations and accreditation reports

The internal evaluation and accreditation reports showed that changes in the curriculum were required to ensure adaptive expertise development, enhance reflection and support continuing faculty development (see Groenier et al. [10] and Miedema [17] for a more elaborate discussion). First, adaptive expertise development needed to be supported more for clinical skill acquisition, such as surgical skills. Instead of focusing on skill automation, innovating the medical

intervention in which these skills are needed should be encouraged. Second, students needed more practice in critical reflection through experience-based learning, such as reflecting on professional development during internships. Finally, faculty needed continuous support in translating their knowledge and skills to the technical-medicine domain and integrating core concepts from different domains into the curriculum.

3.2 Interviews

3.2.1 Characteristics of Technical Physicians

There are currently over 450 alumni of which 63% worked in a hospital in 2018. Thirty TPs (22 male) agreed to participate in the interview study (average number of years since graduation = 4.3 years; standard deviation = 2.0; range = 0 – 9 years). Most TPs worked as a PhD student (n = 9) or in the position of Technical Physician (n = 8).

3.2.2 Effectiveness and efficiency

TPs mentioned an increase in effectiveness and efficiency for several aspects of healthcare as a result of their practice. They related an increase of effectiveness to more effective clinical processes involving the use of medical technology, an increase in quality of care and more patient-specific interventions. An increase in efficiency was attributed to being able to combine technical and medical knowledge in clinical practice, shorter duration of interventions and increased accuracy of interventions. Not all TPs noticed an increase in effectiveness or efficiency. This was mostly due to their work being part of research rather than care and because they felt it was hard to quantify effectiveness or efficiency.

3.2.3 Safety

The majority of TPs reported an increase in safety of the clinical interventions they were responsible for. They related this increase in safety to their mastery of technical knowledge, the application of safety margins and outcomes, and risk management during the interventions. Some TPs stated that they were not certain if safety had increased as a result of their practice. Also, some mentioned that the safety precautions they put in place could also be safeguarded by other healthcare professionals.

3.2.4 Innovation

All TPs stated that they contributed to innovation in healthcare. The innovations consisted of, among others, the development of new tools for diagnosis and therapy, finding new applications for existing technology and establishing standards and protocols for safe and effective use of technology in healthcare.

3.2.5 Task shifting

TPs also commented on the possibilities to shift their tasks to other healthcare professionals, in other words: can someone else do their job? Most agreed that it was possible to shift (some of) their tasks to others, but only at a cost. They mentioned that task shifting would result in more manpower and resources or that the quality of work would be reduced. Others stated that their tasks could not be replaced because others lack the required technical-medical competencies. Also, some TPs indicated that they felt it was hard to quantify.

4 CONCLUSIONS AND FUTURE DIRECTIONS

The Technical Medicine curriculum aims to prepare their graduates for building bridges between engineering and medicine, that is to be able to "translate medical technology into effective, safe and innovative patient care." (Groenier et al. [10], p. 629). From our preliminary analysis of the interviews with practicing TPs, we conclude that, from their perspective, they contribute to more efficient and effective clinical processes, to increased patient safety and to innovating medical interventions. However, there was also a number of TPs who did not perceive a clear impact of their practice on improving the quality of healthcare. One of the reasons for not observing an impact was that indicators such as effectiveness and safety are hard to quantify. Also, the majority of TPs work on research projects in hospitals and those TPs state that they see a potential for impact of their work in the future instead of already having an impact on current clinical practice. We agree with De Haan et al. (2019) who state that barriers of the social setting, in this case hospitals, negatively influence the impact of TPs practice. Our results should therefore be viewed in light of these barriers that TPs might experience in clinical practice.

From our analysis of the evaluation and accreditation reports we learned that supporting the integration of and translating between the engineering and medical domain is not only relevant for educating TPs, but also for professional development of our faculty who have diverse disciplinary perspectives. This implies that educational program management needs to actively provide tools and support for faculty to translate between domains when designing education for Technical Medicine students.

4.1 Future directions

To better equip future TPs for their clinical practice, we need to understand how the barriers and facilitators mentioned in the De Haan et al. [9] study are related to our TPs perception of their impact on quality of direct patient care. Do TPs who experience few social barriers feel that they can contribute more to quality of direct patient care? How do TPs in different social settings cope with the challenges and barriers of an emerging profession? Also, in the current study we only examined the TPs' perspective. In a follow-up analysis, we will explore medical specialists' perception of the impact of TPs' practice on the quality of direct patient care in their organisation. Furthermore, an important educational question that remains to be

answered is whether our theory-inspired instructional principles result in adaptive expertise development in practice.

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A LAB-IN-A-BOX PROJECT ON MECHATRONICS

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Conference Key Areas: *Challenge based education, maker projects; Interdisciplinary education*
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ABSTRACT

A maker project is combined with theoretic courses on dynamics and control to an integrated module on mechatronics. The combination of theory and practice aims at enhancing student motivation and learning. However, a maker project with a full design cycle (design, realisation and testing) is challenging from an organisational and financial perspective, particularly for large numbers of students. This paper considers the design of a maker project and supporting hardware to enable to overcome these issues. The project follows a structured design cycle to be time efficient. The hardware consists of a lab-in-a-box with reusable standard components and easy-to-produce custom design components. This allows fast realisation at low cost, while offering substantial freedom of design. The results of a student questionnaire show improvement of the student appreciation and report grades show improved learning.

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1 INTRODUCTION

1.1 Background

The Bachelor programme of Mechanical Engineering (BSc-ME) at the University of Twente is organised in thematic modules of 15 EC along the university's educational model [1]. The last module in the second year is *Mechatronic Design*. Mechatronics is an interdisciplinary field combining mechanics, electronics and control. The module consists of two lecture-based courses *Dynamics* and *Systems and Control,* and a *Mechatronics Design* project. In the project the students combine the theory from the courses to complete a full design cycle by architecting, designing, constructing, testing and validating a precision mechatronic system.

1.2 Problem statement

Seeing theory at work and completing a full design cycle in a single project is motivating for Mechanical Engineering students as it appeals to their practical mindset and it provides them with the possibility to autonomously work on the mastery of the material. However, providing the ability to actually realise and test the design is challenging from an organisational and financial perspective. This is particularly challenging by a growth in the number of participants to over 120 students, while the students prefer working in smaller groups.

1.3 Outline

This paper describes how the project and the supporting hardware were concurrently designed to implement this full design cycle project while coping with organisational and financial constraints. First the educational design is discussed, including the learning objectives, the main challenges, the project structure, the supporting lab-in-a-box hardware and the assessment. In the results section, the exam scores and evaluation results are provided and discussed. The paper ends with a short summary of the main results and the potential for future improvement.

2 METHODOLOGY

2.1 Learning objectives

The learning objectives are formulated in terms of what the student should be able to do through and after the project:

1. Design a precision mechatronic system from performance specifications by integral design of a PID-like controller and the nominal and parasitic dynamics of a single degree-of-freedom mechanical subsystem.
2. Design and execute a measurement procedure to obtain the steady-state and frequency response of a mechanical system.
3. Implement and tune a digital PID-like controller for a mechatronic system for the measured response and the specified performance and stability margins.
4. Evaluate the performance of a precision mechatronic system by designing and executing effective experiments and by verification of the performance specifications from the experimental results.

These learning objectives enable students to go through a complete design cycle of a basic mechatronic system. The ability to conceive, design, implement and operate (CDIO) has been identified as the context of engineering practice providing a setting for the education of engineers [2]. It thereby contributes directly to the final qualifications of the bachelor Mechanical Engineering programme.

2.2 Challenges in the project design

Predecessors of the considered Mechatronics project have been running for over 20 years. The project used to combine the aforementioned learning objectives with learning objectives on construction principles for precision mechanisms. At the introduction of the Twente Educational model [1], the project was split in a project on mechanical design and a module on dynamic modelling and control. These projects were allocated to two separate modules. In the time between these modules, the mechanism designs were being produced by a team of technicians. This implementation of the project had several downsides related to the hardware; The realisation of the designs was costly. The students had to be grouped in large teams to be able to timely realise all designs. After production it was hard to modify the design in case of flaws in design or production. Furthermore, the electronic hardware was non-portable forcing the students to work in crowded rooms, while the limited availability of the electronic hardware required time-sharing. These issues lead to poor student appreciation and motivation. An increase in the inflow of students even aggravated these issues.

To overcome the aforementioned issues the project was redesigned. In the end this should increase student motivation and learning. Considering that most issues are related to the hardware used, the hardware had to be redesigned (see section 2.5) along with the educational aspects (see sections 2.3, 2.4 and 2.6).

2.3 Project structure

In 2013, the University of Twente introduced the Twente Educational Model [1]. In this model, the curriculum consists thematic 15 ECTS modules based on project led education. The project thereby has a central place in the 10 week's module. It allows students to apply and practice the theoretic knowledge in the project. Specifically, in the 2nd year's Mechatronics module of the Bachelor Mechanical Engineering programme, the project (5.5 ECTS) requires students to model the dynamic behaviour of a mechanism using the theory from the *Dynamics* course and to control the motion using the theory from the *Systems and Control* course. The students need already quite extensive knowledge from the latter course start with the project. Thereby, the lectures of this course are scheduled in weeks 1-5, while the project is scheduled in weeks 5-9 (see Table 1). The assessment of both courses and project are scheduled in the 10th week. This way the students can use the theory from the courses in the project to deepen the theoretical knowledge before the course's assessments.

In week 2-4 three introductory practicals are scheduled to train the procedure to measure a frequency response and implement a PID controller, learning objectives 2 and 3 respectively. Furthermore the experimental work in the practicals is linked to the theory from the courses. Concurrently students can familiarize with the hardware that is used later for the project. In weeks 5-9 the actual project is scheduled, in which the theory of the courses is transferred to the design and evaluation of the mechatronic system of the project. The project work relates to all learning objectives as detailed in the next paragraph. Through the project work the students can get a deeper understanding of the theory and the relation between the theoretical disciplines involved.

The project is structured along the lines of the V-model [3] (see Fig. 1), which is a well-known model for the systems engineering process and closely links to the previously mentioned CDIO context of engineering practice [2]. This ensures students take the right sequence of steps, which also enhances time efficiency. A concept of operations for the system is provided to the students. Based on this concept, the students have a week to set up the architecture and requirements for the mechanical and control subsystems. Subsequently students have a week for the detailed design of these subsystems, including the implementation of the controller. The hardware (see section 2.5) allows implementation of the mechanism in one day and in the rest of the week the students measure the response of the mechanical system to verify compliance to the design and to retune the controller if needed. Finally, in the last week, the students verify and validate the overall performance of the system and evaluate the design.

Table 1. Schedule of the module

Course\Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Dynamics 2	lectures									exam
Systems & Control	lectures									exam
Project		practical				architect	design	verify	evaluate	exam

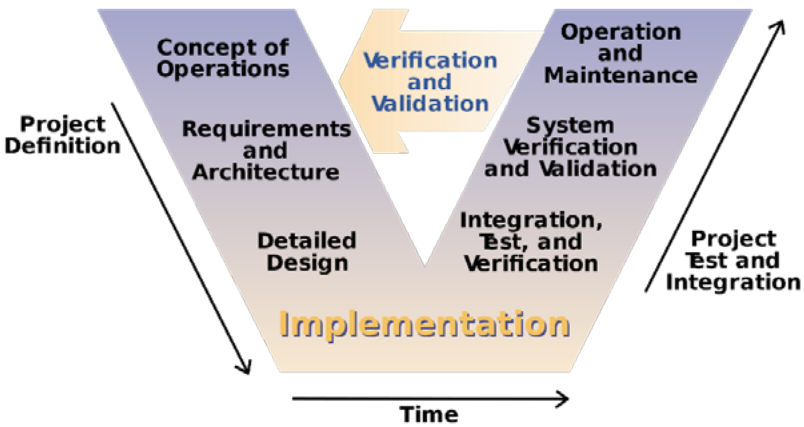

Fig. 1. The V-model of the systems engineering process (adopted from [3])

2.4 Project kick-off and support

Students are grouped in teams of 6. This relatively small group size stimulates student involvement and allows effective work distribution. All groups are provided with the same project description, which includes the assignment and organisational information. The project assignment is specified in terms of the required system behaviour and deliverables. The required system behaviour sets the goal of the mechatronic system to be realised. From the required system behaviour, the students have to architect the subsystem requirements and the way to realise these in a design. Differences in the routes taken by the groups yields different design implementations to reach the goal. The deliverables set the aspects to be considered in the design process and to be included in the project report. The specification of the required system behaviour and deliverables provides freedom in the design and the approach, while the outcomes are comparable for reliable assessment.

The project information is also explained orally in a kick-off lecture with the opportunity to ask for clarification. During the project a weekly lectorial is scheduled. In each lectorial, the deliverables and the supporting theory for the next phase are detailed. Further support is provided by teaching assistants during the experimental work and by question hours with teaching staff for the theoretical aspects. Students are also stimulated to pose questions on the discussion forum of the online teaching environment. Finally, each project group has a tutor, who keeps an eye on the planning, the group dynamics and spots free-riders. Students are free in organising the group work and have ample experience on working in groups from prior projects.

2.5 Project hardware: standard and customised components

Lab-in-a-box hardware is developed to support the project. The hardware allows fast realisation of the design, while it offers substantial freedom in design. This is realised by a combination of modular standard components and easy-to-produce custom design components.

The main modular components are holed blocks of stainless steel with matching fasteners. These blocks are metric versions inspired by the MechBlocks of Motus Mechanical [4]. The use of these components was inspired by the use of MechBlocks in the 2015 Challenge of the American Society of Precision Engineering. These mechanical components are supplemented by a voice-coil actuator and a position sensor to constitute a mechatronic system. The lab-in-a-box is shown in Fig. 2.

The students can design custom components that can be manufactured by laser cutting of steel plate. These components can be produced in one day. Typical custom components are brackets and flexure hinges. Flexure hinges are typically used in precision mechatronic systems as considered in the project. The theory of flexure hinges is learned in the prior module, while it is also an active topic of research in the department [5]. The design of the flexure hinges is important for the

dynamics of the mechanical subsystem and the eventual performance of the mechatronic system.

In addition to the lab-in-a-box mechanics, an electronics box is provided. This electronics box can be connected to the actuator and sensor, and its microcontroller can be programmed on the student's laptop via Matlab-Simulink. The electronics box is also used to control a linear stage during the practical. The lab-in-a-box and electronic box are portable and can thus be used at any convenient location (Fig. 3).

Fig. 2. The lab in a box

Fig. 3. The lab in a box in use

The actual realization of the mechatronic design and the experimental verification provide the students with the experience that reality deviates from theory, typically by unmodelled phenomena. They have to track and explain deviations, which requires them to combine modelling and experimental skills and provides insight in the interrelation of the disciplines. The lab-in-a-box allows adaptation of the design and retuning of the controller to adapt the system to these new insights.

The lab-in-a-box and the linear stage can be reused for various cases over the years. In the last two years they have been used to create a laser tracking system and an XY-plotter (Fig 4). The reusability allows depreciation of the hardware investment (mainly the mechanical blocks) over multiple years. The laser cutting of components are the only low recurring costs. This reduction in cost allowed an investment in sufficient hardware to reduce the group size to the desired number of 6 students even with an increasing number of students.

Fig. 4. Examples of design cases. Left: laser tracking system. Right: XY-plotter

2.6 Assessment of the project

The module is assessed through four components. First, the students have to hand-in a practical report to show they have trained the theory before the start of the design project. Secondly, the specified deliverables of the project are to be documented in a report. Major deliverables are on the level of insight, e.g., a discussion of the fundamental limitations in the design, an explanation of the differences between the model and the experimental results and an evaluation of the eventual design. Thirdly, they have to demonstrate the operation of the actual system, to verify the document performance has indeed been realised. Fourthly, the students have to do an individual written exam, to assess the individual achievement of the learning objectives and thereby prevent free-rider behaviour. The individual exam consists of questions on the steps taken during the design process.

3 RESULTS

Table 2 shows the results of the students and the overall student appreciation indicator from the yearly *Student Experience Questionnaire* (SEQ).

The redesigned project has been running since 2018. It has been observed that students are more active and enthusiastic. This is reflected by the clear improvement in the appreciation indicator in 2018. The improvement from 2018 to 2019 are probably related to solving some teething problems and further finetuning, particularly the lectorials and the portable electronics box have been introduced. From the 2019 questionnaire, some quotes from students on the strengths of the module are: “The idea of the practical part of the project is very motivating and interesting.”, “The integration of the different subjects in the project” and “The practical part of the project does give a lot of insight into control systems.” These clearly show the motivational effect and addition insight of having hardware at work, in line with the intended outcome of the project.

Improvements on the achievement of learning objectives are visible from the average grade on the reports. On the other hand, the grades on the individual exam drop severely in 2018. This is probably related to more complex questions in the exam. Splitting compounded questions and a discussion of typical exam questions in the lectorials already improved the exam score in 2019. However, students still feel the exam is somewhat disconnected from the project work. Further improvement on this issue is needed.

Table 2. Results of the exam and evaluation scores for the project

	Students graded	Average grade report	Average exam grade	Students in evaluation	Appreciation indicator
Scale	-	1-10	1-10	-	1-5
2017	104	5.1	6.5	33	2.5
2018	94	5.9	5.3	26	2.8
2019	122	6.4	5.7	31	3.3

4 SUMMARY

The paper shows the design of a project in which students complete a full design cycle, including the realisation and testing of a mechatronic system. The project is meant to integrate and practice theory from courses to enhance insight. The project is aligned with the V-model of the systems engineering process to enhance time efficiency. Realisation of the hardware in limited time is enabled by the use of lab-in-a-box, providing standard components that are combined with easy to produce custom design components. Seeing theory at work is highly motivating as reflected by observations and results from the student questionnaire. The grades on the reports resulting from the project also improved considerably.

As a future enhancement, the introduction of 3D printing is considered. This extends the ability to use custom parts that can be produced quickly. Another potential improvement is the use of e-learning applications for preparation of the practicals [6, 7], which could enhance the learning effect, while reducing supervision workload. The most urgent point of improvement for the project are the individual exams that assess individual performance of the student. Although exam questions are intended to test knowledge on the steps taken in the project, students experience the questions to be difficult and not testing their involvement in the project.

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TEACHING AND LEARNING TECHNICAL AND MANAGERIAL LEADERSHIP SKILLS THROUGH SCENARIO-BASED LEARNING

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Keywords: *professional skills, leadership, management, professional education*

ABSTRACT

Today's scientists, engineers, and researchers, through traditional educational programs, have developed deep technical, analytical, and problem-solving skills. However, many lack the leadership, people management, knowledge transfer, and communication skills needed to be successful leaders. To fill this gap, MIT Open Learning along with faculty from MIT Sloan Management, the School of Engineering, and the Gordon Engineering Leadership Program developed the "Leadership Academy for Scientists, Engineers, and Researchers" (LASER). To successfully lead change within an organization, this audience needs a proven framework to fully understand organizational change. LASER utilizes an MIT framework known as the "Three Lenses" that provides three perspectives (strategic design, political, and cultural) to determine what data is being perceived in an organization, how to interpret the data, and how to view problems from multiple angles. The Three Lenses was chosen due to its ability to be transferable from an online classroom to the job site.

LASER's pedagogical model focuses on five types of educational activities: assess, explore, practice, apply, and share. The core of the learning material developed for LASER was built around the premise of transferrable skills and application in the real-world. To make the real-world context come to life, the delivery of the course content utilizes several strategies, one being the concept of scenario-based learning (SBL). SBL provides learners the ability to practice using what they have learned and applying it to a real-world scenario of a problem they are likely to encounter. This paper will further elaborate on this concept and provide examples.

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1 INTRODUCTION

Today's scientists, engineers, and researchers, through traditional educational programs, have developed deep technical, analytical, and problem-solving skills. However, many lack the leadership capabilities (people management, knowledge transfer, and communication skills) critical for success [1, 2, 3]. In technical professions, leaders need different skills to thrive. According to Grenny & Maxfield (2016) "The tech industry's combination of high-velocity competition, complexity, global talent, and interdependence among rivals makes it a truly unique environment, requiring a distinct set of leadership skills" [4]. To this end, a business unit within the Massachusetts Institute of Technology (MIT) called, "MIT xPRO" sought to address this need by developing a new online leadership program for the technical professional. This program became known as the Leadership Academic for Scientists, Engineers, and Researchers (LASER).

1.1 What Gaps Are Being Filled

LASER was a historic cross-Institute collaboration between the MIT Open Learning Office, faculty from MIT Sloan Management, the School of Engineering, and the Gordon Engineering Leadership Program leadership, bringing forth multiple experiences from MIT. LASER was designed uniquely in the sense that the content was created for a technical audience. From first time managers, individual contributors, and mid-level managers, anyone in this audience will find content relevant to their position. While most technical professionals have been trained to develop their hard skills, LASER focused on human skills. Human skills can be defined as "non-technical skills and attributes, which will be immune from machine replacement for the longest and will equip humans to thrive" [5]. According to Westerman & Stump (2020), "Digital and technical skills are critical to emerging jobs and industries, but it is the uniquely human skills that will be immune from machine replacement for the longest and will ensure individuals can thrive in the new economy" [5]. These human skills included growth mindset, critical thinking, collaboration, self-awareness, and negotiation among other skills. These skills were all necessary to include with the purpose of giving technical leaders the tools to become change agents. With these human skills in mind, LASER provided an opportunity for early and mid-career technical professionals to further develop their competencies as leaders in the workforce.

1.2 Three Lenses

For technical leaders to develop a strong skill set and to lead change effectively, being able to understand multiple perspectives is paramount. To aid in the understanding of perspectives, a framework from MIT's Sloan School of Management was selected called, "The Three Perspectives." This framework provided three perspectives on organizations, problems, and change efforts. The three perspectives or lenses, are known as the strategic design lens, the political lens, and the cultural lens [6]. Each of these lenses were important to navigate the dynamics of the formal side of organizations, to navigate the dynamics of the people

with relationships, power, and influence, and to navigate the dynamics of the cultural side.

LASER comprised of four online courses with the first three focused on one particular lens. The first 4-weeks course, “Understanding Organizational Strategy and Capabilities,” focused on the strategic design lens and designing organizations to achieve certain outcomes through a better understanding of the organizational mission, purpose and goals. These components are crucial to planning purposes and provide alignment to important measures of performance such as effectiveness and efficiency. The second 3-weeks course, “Negotiating and Applying Influence and Power,” was designed to focus on the social context and relational side of an organization. The outcomes from this course were to understand conflict and how to gain cooperation from individuals and groups within an organization. The third 3-weeks course on the cultural lens was titled, “Leading Change in Organizations.” This course was designed to leverage and navigate cultures and networks within an organization at any level.

After experiencing the three courses, learners transitioned to the final 3-weeks course in the online program called, “Discovering and Implementing Your Leadership Strengths.” This course transitioned the mindset and the learning experience of looking through different lenses to focusing on the inner self. Learners in this course discovered and analyzed their leadership traits and experienced visioning exercises to profile their own styles of being a leader and a change agent.

1.3 Pedagogical Model

In order to deliver the best learning experience, the LASER Program utilized a pedagogical model based on research from evidenced-based instructional design practices, learning sciences, and neuroscience. The design vision of the LASER curriculum, pedagogy, and learning environment is based in the latest neuroscience and cognitive behavioral science on learning, as well as best practices from decades of MIT’s pioneering work in digital learning [1]. Collaborating with faculty researchers in the MIT Integrated Learning Initiative (MITili), LASER puts evidence-based insight into action, implementing such digital learning innovations as modular content, interleaved assessments, visualizations and simulations, and interactive, online tutors with adaptive hinting and rapid feedback. This model contained five different elements of learning with exploring, practicing, applying, sharing, and assessing.

These principles followed MIT’s *mens et manus* motto, meaning mind and hand. Just as MIT’s founders were promoting education for practical application, LASER followed the same path as each course focused on teaching tangible real-world skills, their applications, and how they would transition to the workplace. To acquire a significant amount of knowledge within the duration of the online program, learners experienced hands-on activities and real-world applications which were established as the fundamentals for the learning process. Learners were expected to devote about 12 hours of work per course (3-4 hours per week). The elements of learning, considering our pedagogical model [7, 8, 9, 10], were segmented into:

- Explore: Students learn core concepts through watching engaging videos and reading research-based papers and articles.
- Practice: Through multiple choice questions, scenarios, and simulation activities, students practice concepts without an impact to their grade.
- Apply: Via case studies, essays, and self-reflection, students apply conceptual material to solve problems and take stock on how principles apply to their jobs.
- Share: Through peer-to-peer discussions and surveys/polls, students reflect on what they have learned, comment on other students' experiences and expand their knowledge through others' insights.
- Assess: Using pre- and post-assessments, peer assessment tools, as well as summative assessment instruments, students are evaluated on their understanding of the material and their ability to apply it to the workplace.

Figure 1: LASER Pedagogical Model

By following these learning practices, LASER leveraged MIT's wealth of knowledge and experience in the engineering, entrepreneurial, and leadership spaces, as well as its advanced approach to online learning.

1.4 Scenario-Based Learning

To create an effective and optimal learning experience for real-world applications, this program's curriculum was designed using a learning technique known as, "Scenario-Based Learning" [11]. Scenario-Based Learning or SBL, uses hypothetical or real-life scenarios to support active learning strategies. These were based upon the mentioned case studies throughout the program and involved learners imagining themselves in the scenario. By going through this process, learners needed to use critical thinking and decision-making skills throughout each part of the required problem. Learners were also able to practice and apply these skills in a safe environment where learning from mistakes and sharing their

experiences with other learners was encouraged. SBL was selected for this program due to the need for technical leaders to be able to apply the learned tangible skills in the workforce.

In order to create effective scenarios, these scenarios were developed by the course team visualizing themselves as being in the position of the learners. Scenarios could be practiced safely within the program's content and aided in the learning of the transferable skills. Problems were drafted based upon the program's curriculum, articles, and videos. Once the scenarios were designed, subject matter experts and faculty members were consulted for their relevancies to a technical professional. To verify their accuracy, the course team had the opportunity to speak to learners from different industries who completed a pilot run of the program. Both quantitative and qualitative methods were utilized to collect, analyze, and apply learner feedback.

1.5 SBL Examples

The following are several examples of the SBL problem types from LASER's curriculum. The first is from Understanding Organizational Strategies and Capabilities. In this example, learners have been introduced to a problem many organizations face called, "The Capability Trap" [12]. This problem revolves around organizations struggling with being able to implement a new idea. Based upon this information a scenario was created with an organization trying to adopt a new project management software, but were facing several challenges with the implementation process. The problem is presented as a package which included directions, a hypothetical email sent by the organization's human resources department, and the challenge the learner is supposed to solve. For this scenario, learners read this prompt:

"Imagine working for a manufacturer who specializes in futuristic technology. After months of research, your human resources department has concluded that a new type of project management software needs to be implemented company wide. The first time you heard of this research was only a few days ago and you haven't been informed of how this new project management software will be more efficient than your current one. The slow research process went over its expected amount of time and now, HR has quickly scheduled numerous training sessions on your calendar that overlap your weekly scheduled meetings. After a week goes by, you received an email containing a broad message about how and why this software was chosen, with a note at the bottom mentioning how correct utilization of this software will be included on your upcoming performance evaluation."

This message was then followed by an email acting as the HR representative from the prompt:

New Software Launch

HR

Human Resources Department <message@hr.com>
Luke Hobson
Saturday, February 2, 2019 at 8:01 AM
Show Details

Good afternoon,

We are excited to announce that after careful consideration, we will be utilizing Ira as our new project management software! Due to time restrictions, we have already scheduled training sessions for each supervisor. These training sessions are *mandatory*. After these sessions have concluded, it is expected for Ira to be on all performance evaluations moving forwards.

Please contact us if you have any questions.

Thank you,

Luke Hobson, Ed.D
AVP, Talent Engagement
Human Resources

Figure 2: SBL Email

This example had learners use critical thinking skills to predict the outcome of this process. A reflection question was also asked following this SBL example to have the learners think about their own organization. The reflection question in this example ask learners asked, “Identify at least one example of the capability trap within your organization. Knowing what you know now, how would you approach this problem?”

Another example can be seen in the Discovering and Implementing Your Leadership Strengths course. Learners performed a personality test to better understand who they are as leaders. Learners are presented with the case of a company attempting to launch a new product facing various issues (production challenges, issues with the Director of Operations, Issues with the Head of Regulatory Affairs, and Issues with on-boarding influencers) and need to act as one of the roles of the scenario (a new employee recently promoted as general manager). After reading the case, learners were asked to share their answers on a discussion platform thread:

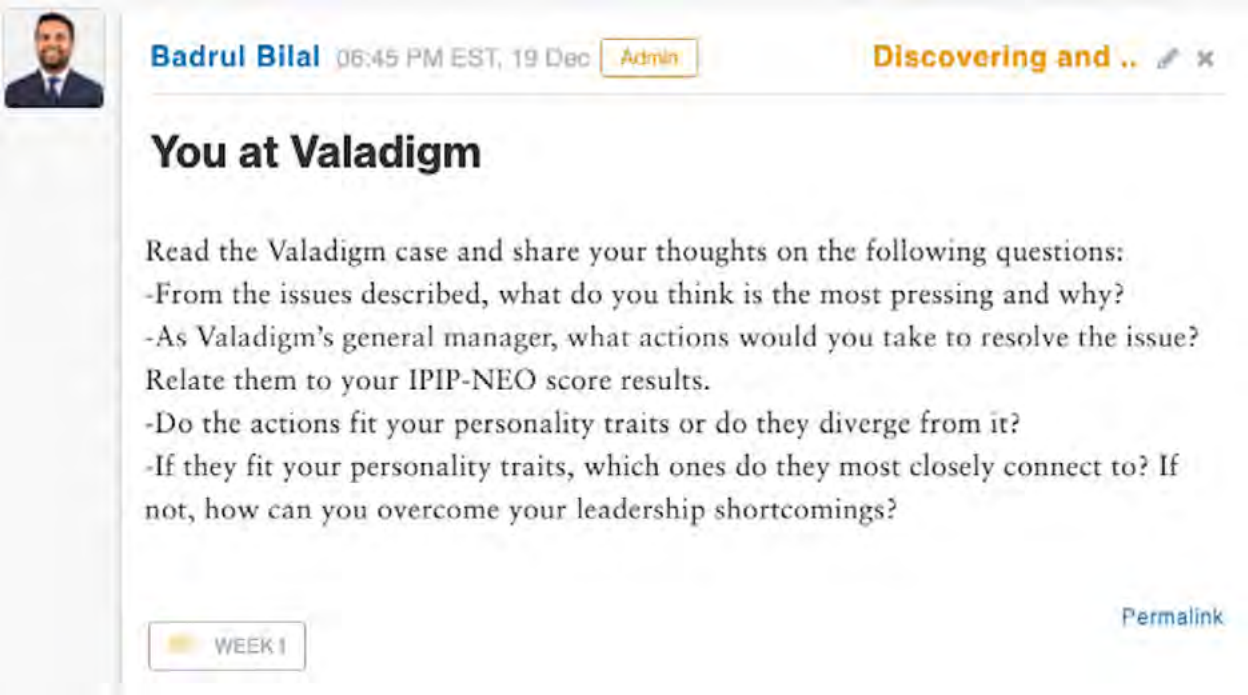

Figure 3: SBL Discussion Platform Thread

By using critical thinking skills and applying the course content, learners had to decide what actions to implement to successfully resolve the situation. This scenario also had learners relate to their personality traits scores, analyze why they would act in that direction, and how their traits impacted their leadership style.

2 CONCLUSION

To further develop tomorrow's technical leaders, MIT Open Learning and other business units within MIT designed the Leadership Academy for Scientists, Engineers, and Researchers (LASER). Learners of this program were supplied with the Three Lenses framework to assist with leading change within an organization. This framework provided perspectives on strategy, politics, and culture to understand organizational change and focused on transferable skills from the online classroom to the job site. LASER's pedagogical model focuses on five types of educational activities: assess, explore, practice, apply, and share. The delivery of the program's content utilized several strategies for effective online learning with scenario-based learning (SBL) in particular, being highlighted. SBL provided learners the ability to practice using what they learned and apply those skills to real-world scenarios of a problem.

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WORKING-LIFE-INTEGRATED ENGINEERING STUDIES – SERVICE MARKETING PERSPECTIVE

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ABSTRACT

Universities are keen on following the developments in working life as they find it important to keep education up to date and to support students' career development. Working life is under constant change and many of the working life requirements are industry specific. Organizations probably have several reasons for university co-

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operation. In this study we assume that 1) co-operation in education generates value for organizations and 2) this relationship can be regarded as service marketing. We utilize the concept of service marketing within the industry-education co-operation and present a case study of re-arrangements of engineering studies at one small European university.
Service marketing concept focuses on the whole process of marketing, not only on the marketing communication. The process concerns value creation and co-creation by service supplier and customer. A service is consumed at the same time it is produced and therefore, cannot be stored. Further, supplier provides recourses for customer's use, but the actual value emerges in customer's process of turning service into value.
The results of our discussions are in line with the concept of service marketing. Value to the industry partner is created in an interaction between that partner and a student. Students are thus evaluated on both the course completion and the value they produce for the client. This highlights also the role and importance of the commitment by the customer, i.e., the participating company. As a summary our results indicate that service marketing perspective is worth further investication in university education development. We also propose a set of recommendations to utilize better the charactistics of service marketing in education.

1 INTRODUCTION

1.1 Prologue

Working life is under constant change and many of the working life requirements are industry specific. This means that, for university educators, working life skills are a moving target. In this paper, we utilize the concept of service marketing into the industry-student cooperation and present a case study about analyzing experiences at one small European university.
Marketing is a videly used term and it has several definitions. The classical definition by Kotler [1] states: "Marketing is a societal process by which individuals and groups obtain what they need and want through creating, offering, and exchanging products and services of value freely with others." This definition describes marketing as a process focusing on value creation within producsts and services, a notion which is important for this paper. Kotler also notes that according to the so called managerial definition by The American Marketing Association, marketing (management) is the process of planning and executing the conception, pricing, promotion, and distribution of ideas, goods, and services to create exchanges that satisfy individual and organizational goals. This defition brings the concept into the business world, but the most crucial notion for this study is that marketing is much wider concept than just marketing communication. It is a process producing value and it implies interaction between different parties.

This paper aims to open up discussion on the suitability of the concept of service marketing in consideration of university education, within the case of university-industry co-operation. In this layout, university courses are regarded as service products. However, the aim is not to discuss the filosofical foundation of university education or for example, the so-called third mission of universities any further. This paper indroduces the results of our discussions that were stimulad by the congruence between our findings and the concept of service marketing. It should be noted that the course set up presented in this paper was designed before the introduction to the concept of marketing, the results were not guided to any direction with any conceptual framework.

1.2 Service marketing

Similarly as marketing, service marketing concept focuses on the whole process of marketing, not only on the marketing communication. The process concerns value creation and co-creation by a service supplier and a customer. In a few respects, services are clearly different from products. These features are often called as IHIP attributes [2]. The IHIP attributes are intangibility, heterogeneity, inseparability of production and consumption, and perishability. Intangibility means that services are performances, they do not have a physical existence, and it is the most important factor differentiating services from products. Even though services can include some degree of tangible elements, the service process itself is an intangible performance. Heterogeneity has a dual meaning. Firstly, there is a great heterogeneity among service processes and service providers. Secondly, the service process in a company is found to be heterogeneous because of variation in its employees and in its customers, for example due to their needs and expectations. Perishability distinguishes services from goods in that they cannot be stored in inventories. Further, it is important to notice, that supplier provides recourses for customer's use, but the actual value emerges in customer's process of turning service into value.

It has been pointed out for example by Lovelock [3] that these characteristics exemplify the fact that services do not have a standard outcome, but the outcomes and their quality differ, depending on the specific customer and the service context. This notion has very important implications for our case, that is, treating university courses as service products for outside organizations. If we accept the above mentioned IHIP attributes concerning also university-industry co-operation in education, it would mean that very little of the value outcome to outside organisations can be achieved by pre-fabricating or by standardizing the courses. Value will be created during the co-operation and much by the student taking part in that process and by the organization in question. This seems to summarise the challenge in integrating education quality systems with the demands of teaching working life skills; that is, to standardise a moving target.

2 METHODOLOGY

2.1 Case study

As Boeije [4] has mentioned, qualitative research is an applicable method for research, when a study has an explorative nature. The aim of this research is to explore the usefulness of the concept in understanding the phenomenon. Case studies typically use direct observation of the events being studied, as well as interviews of the people involved in the events, questionnaires and archived material [5]. Our study builds on an instrumental case study by Stake [6], where the case itself is not spefic, but it provides an opportunity to create a new insight into issue, and offers a stepping stone for further research measures. A special state of affairs that is utilized in this study, is the development of teaching into the direction of benefits for companies.

The case presented here is a curriculum work model which offers the research methodology teaching long before starting the thesis and, on the other hand, prepares students to working-life together with the company already during studies. The whole is made up of basic studies in research methodology, laboratory work course in the corporate environment and subsequent thesis. The implementations are not separate courses, but support the thesis, as shown in Fig.1.

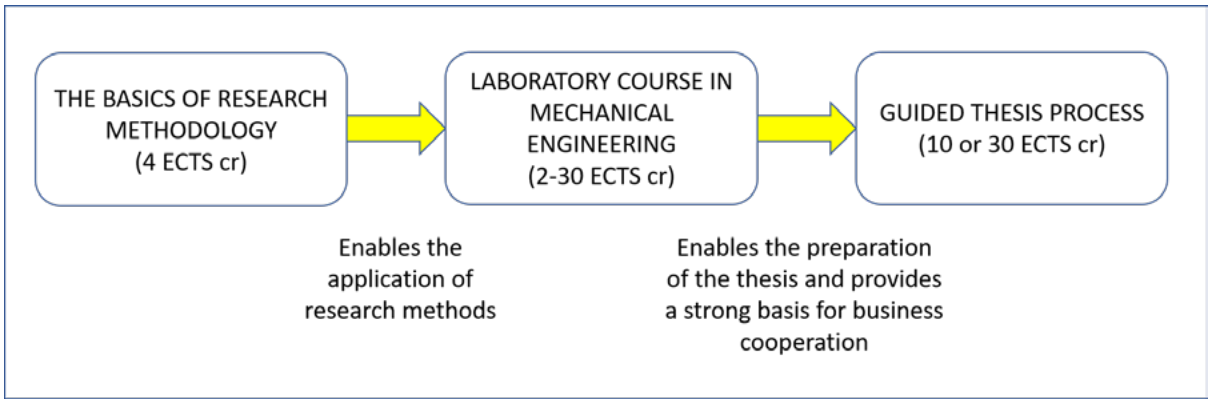

Fig. 1. As part of the curriculum work process that is integrated into working life, the thesis implementation model is used to support the advancement of both international and domestic students. The core of the process lies on three integrated courses.

The main part of the curriculum work is the laboratory work course, the scope of which is 2-30 credits according to the company-oriented project. Flexibility makes it possible to use the course in both bachelor's and master's stages. The course creates the capacity to solve the real problems identified by the companies with a research approach. At the same time, it provides the basis for longer-term business cooperation and allows the preparation and start of the thesis. The course will be carried out as a project that is planned together with the company, the student and

the supervisor from the university. A project plan, follow-up reports and a final report are prepared for the project, reflecting the implementation of a student's plan.

2.2 Interviews

This paper builds on the interviews of teachers and discussions among the teachers and our research group. In the following we present the main results of the interviews.
In this consideration we intentionally focused on teachers. Students are also the main players in the whole setting, but they do not have insight into the changed situation, as they have no actual possibilities to compare their experiences with those of previous year students. We present interviews of three university lecturers, who were actively planning and piloting this new curriculum work model. The interview is based on four questions, and the main part of the replies are presented here (as direct translations to English).

Question 1.
What did you do and what was the change compared to before?

> "The most important thing is the implementation and introduction of a chain of three courses in a company-oriented way. First, the research methodology creates the capacity for a research approach in future interaction between the student and the company. Secondly, the Laboratory Work Course / Individual project work course connects the student and the company to the target company for a long time (up to 20 cr) and lays the groundwork for the thesis and "introduces" the student and the company to each other. Here you learn general project work models and also get to know the target company's project practices and, for example, information systems. The company can "assess" whether the student should be recruited for them, but there are still no salary costs. The scope of the project (2-20 cr) can also be agreed with the company. Third, a supervised and scheduled thesis process helps to solve a company problem in a high-quality and company-oriented manner."

Question 2.
What did the changes mean for the teaching work and the teacher?

> "When planning the content of teaching and arranging student meetings, the special features of the respective business contact have had (have been) taken into account. To some extent, the company-oriented examples have been confidential and have not been used other than in the supervision of an individual thesis. On the other hand, a company-driven "right problem" also challenges the teacher to sharpen his or her own guidance and address the specifics of the company."

"In the long run, I believe that this will accumulate knowledge capital for teachers, and on the other hand, the company will get a solution to the current problem as well as, if desired, from the author of the thesis who is able to solve the problem to the expert himself. To some extent, the supervised thesis process requires more time from the teacher to meet with the student, on the other hand, from the university's point of view, the completion of theses on time is easier. It is also important for the company to get the results of the thesis as planned, usually as part of a larger project."

"The biggest change is the move away from comprehensive structured teaching and project guidance to a more creative model that includes more degrees of freedom and shifts responsibility more towards the student. The transition from teaching to coaching and support requires a particular mental effort; there is also an element that allows projects to fail when not all the threads can be held in the hands of the teacher. Confidence in students is further sharpened as a whole, as well as acceptance of the idea that not everything learned may be easily or unambiguously measured or even at least fully perceived during the project. A key starting point is to build working life and entrepreneurial skills as one of the starting points for lifelong learning."

Question 3
What have the students liked about the whole?

"To some extent, the workload of students has increased, but on the other hand, the guided processes distribute the work more evenly over the entire study period. In the big picture, students like the fact that there are more frequent contacts with the supervising teacher and they get feedback about their own work all the time. Company orientation in the topics of projects and theses (including bachelor's theses) is a motivating factor. Supervising teachers have found the new model useful."

"The students have generally been satisfied with the supervised thesis writing process, the positive feedback came from the fact that teacher meetings have been arranged during the course, so these were felt to be quite useful. There were things to note about the course schedule, especially the placement of the lectures on the calendar. Some had begun to move forward with their work faster than the course schedule was, and thus the lectures were no longer considered useful at that point."

Question 4
What have companies liked about the whole? What have they stated about the results, and in particular about the results brought by this new model?

"Companies actively participate as mentors in courses and are interested in students 'ideas. Mentoring can be seen, for example, in GoFIRM virtual company operations (an operational tool in the course set). There are constantly more topics for project work and theses coming from companies. Companies often have hopes of ensuring confidentiality issues. Companies often emphasize getting results on schedule, but unfortunately there is not always a "required" completion of a degree on schedule. This still requires clarification on both sides so that the benefits for all parties become clear."

"In the big picture, companies consider the opportunity offered to "take a longer trip" together with the student before possible recruitment or starting a thesis to be good."

"So we moved from trenches of separate courses to working together. Important factors were the feedback received from companies on the skills perceived by graduates and the graduates' own perceptions of the skills needed in working life and the operating models implemented there."

3 DISCUSSION AND PROPOSITIONS

We started this study from and with an assumption that 1) co-operation in education generates value for organizations and 2) this relationship can be regarded as service marketing. Our findings of the above mentioned course setting are in line with the concept of service marketing. The interviews imply that the value to the industry partner is created in an interaction between that partner and a student. Despite students' increased independence the industry partners are keen on having a relatively sustaining co-creation relation with the students. Industry partners clearly have their own goals and timelines. Even teachers have a clear role there, the main outcome is derived from industry partner – student interaction.
There are some evidence, that this re-arrangement of above-mentioned courses did produce more value to the industry partners. Direct measurement is not possible as each project is content and context spefic, and the processes of student – organisation co-operation variate. This is also in line with the basic premises of services marketing. Our case did not bring out any evidence that this development would be harmful to education or to its scientific level. On the contrary, it had a positive influence on students' motivation, which in many generated more positive outcomes.
It also seems that students valuate the possibility to interact closely and for a longer time with industry partners, even if they were evaluated on both the course completion and the value they produced for that client. Further, we noticed that the longer time a company partner and student co-operated, the more value was created. This meant also that student's ability to create value was noticed and

her/his changes to be employed evidently got better. This highlights also the role and importance of the commitment by the customer, i.e., the participating company.

Further, following the earlier, the vast body of research on service marketing and managerial literature on the issue may offer tools and concepts to the development of university education in regard to industry co-operation. Therefore, we propose that service marketing is an important perspective in developing university education and definitely worth futher investication. The literature on service marketing suggest that a service is a process that is produced and consumed simultaneously and the value of the service to the customer is generated in the customer's processes. In educational setting this means that the student is assessed other than through the course substance and the related reports or other written assignments.The student is assessed through the effectiveness of his or her collaboration with the organization and the value it provides to the company. The value to be produced for the customer organization is not necessarily the same as the criteria for assessing the substance content of the course. Based on these findings, we make the following suggestions to support the student:

- *Organizing more and longer-term cooperation with the organization*. Both the student and the organization get to know each other, and the opportunities to generate value together improve.

- *Highlighting the procedural nature of the cooperation with organizations during the courses*. As an example, the student is introduced to the principles of process consulting (see for example Schein [7])

- *Highlighting the marketing nature of the cooperation*, for example by including a bried introduction to marketing and sales in the course content (Notice: this need derives from the actual co-operation process, not as a worldview, ideological or other decision).

- *Planning and highlighting the productisation and modularization of the co-operation process for both the student and the organization.* Both of these contribute to value creation, and knowing the process speeds up familiarization and finding a common course of action. However, the student is not an employee of the company, so it is not exactly the same introduction process that applies to the company's own employees. Even the processes of the customer organization are company specific the familarisation to the basic features of service marketing process may help the student to work with the customer organization.

Our findings led us into an important consideration: If we do accept the IHIP attributes of services (mentioned earlier in the text) concern also university-industry co-operation in education, it would mean that value to the outside organisation would derive from student – organisation co-operation. This would mean that taking these principles into account could make it possible to improve students 'chances of being

useful to companies and thereby improve their chances of finding employment after their studies. Even we do not have a rigorous research setting backing up our notions we were surprised at how well these principles explained the findings made in the context of this course setting and also in the past. Based on our findings we suggest that concept of services marketing is definitely worth further investigation.

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ENGINEERING PROJECT TO FOSTER GLOBAL COMPETENCY AND ASSESSMENT OF LEARNING OUTCOMES USING THE PROG TEST

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ABSTRACT

We designed and have been executing a cross-cultural engineering project since 2013. This engineering educational project was designed to foster innovative and global engineers and scientists based on multidisciplinary, multinational, and industry-academia collaborative project-based learning. The students participated in the project were first-year graduates and third- and fourth-year undergraduates. There were various nationalities including Japanese, Thai, Indonesian, Cambodian, Malaysian, Vietnamese, Chinese, Singaporean, Mongolian, German, Polish, Dutch, and Brazilian. The project themes were related to Sustainable Development Goals (SDGs) such as energy, transportation, environment, poverty, natural disasters, and education as well as practical issues in industries. Multinational student teams were required to not only identify and define social, technical, and interdisciplinary problems but to design and prototype solutions as well.

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The quality assurance of the educational program was achieved by analysis of the results in (1) learning outcomes based on rubrics and (2) a generic skill assessment test of the PROG (Progress Report on Generic Skills). The PROG assesses competencies in working skills, personal skills, and problem-solving skills. It is one of the commonly used measurement methods introduced to 470 higher educational institutes in Japan. This paper shows comparative data of average PROG scores among global workers in Asia, model domestic workers, and university students. The global workers marked higher scores than other groups at all of the survey elements particularly in “relating with others,” “team management,” and “self-control.” Furthermore, it was proved that cross-cultural engineering project contributed to developing these three elements of competencies.

1 INTRODUCTION

In a society where rapid technological innovations and environmental changes are developing on a daily basis, the models of human resources developed in universities and field trainings are significantly changing. In the field of engineering education, the present goal is to develop human resources that can solve social issues, such as Sustainable Development Goals (SDGs), and create more innovations, including products and services with new values. Moreover, the development of soft skills, such as communication and leadership skills, is required in addition to the acquisition of in-depth knowledge and other professional skills.

Higher educational institutions have begun to incorporate the development of global competencies into their educational goals. For example, the Modularising Multilingual and Multicultural Academic Communication Competence project, which was funded by the European Commission, created a learning outcome index centered on linguistic communication, and it encouraged its use for assessments [1]. In addition, in North America, the Association of American Colleges and Universities (AAC & U) created the Global Learning VALUE Rubric and set six evaluation items [2]. Moreover, the Belief, Events, and Values Inventory (BEVI) [3], the Global Perspective Inventory (GPI) [4], the Intercultural Development Inventory (IDI) [5], and the Miville-Guzman Universality-Diversity Scale Short Form (MGUDS-S) [6] have been developed and used by many educational institutions in various countries to assess learning outcomes.

The global competency of human resources in science and engineering has gradually expanded from solely focusing on skills and knowledge to attitude and identity as the need for understanding and respecting different cultures and fields, and having a global perspective. Those dimensions are often overlapped with different areas of expertise. As a characteristic of engineering education, many previous studies have mentioned the necessity for the ability to perform professional work in a global environment. In other words, technical human resources are not only required to have specialized knowledge and skills, but they also need to have foreign language skills and the ability to adapt in intercultural environments and communicate with people from around the world while applying their skills and knowledge in practical workspaces.

In this study, an engineering educational project was designed to foster innovative and global engineers and scientists based on multidisciplinary, multinational, and industry–academia collaborative project-based learning. The quality assurance of the proposed project was achieved by analyzing the (1) learning outcomes based on specific rubrics and (2) a generic skill assessment test of the Progress Report on Generic (PROG) skills. The PROG assesses competencies in working skills, personal skills, and problem-solving skills. It was proven that the cross-cultural engineering project significantly contributed to the development of the above-mentioned four competency dimensions.

2 GLOBAL PROJECT-BASED LEARNING (PBL) FOR GLOBAL HUMAN RESOURCE DEVELOPMENT

2.1 Global PBL

Human resources that demonstrate leadership and innovation in global environments are required. In addition, teamwork between people with different specialties, backgrounds, and cultures is now vital, as well as a methodology that can integrate the knowledge and skills among them. Thus, innovation for education including the methodologies and practical training that create new values is necessary for all human resources in science and engineering, and its implementation is required in all undergraduate and graduate schools.

As a training program for future engineers and scientists, Shibaura Institute of Technology annually implements 80 global PBL courses in Japan and overseas. Those courses can be categorized into two broad types. One is a single discipline type including mechanical engineering, electrical, and electronic information engineering, and construction engineering, and another is a cross-disciplinary type, which crosses multiple disciplines and fosters multidisciplinary students. The project themes for the cross-sectoral global PBL courses are relevant to social issues, such as the SDGs. Participants are demanded to investigate cross-sectoral problems and propose their solutions with innovation by tackling the serious issues in industries and local communities. Generally, those themes cover a wide range of sectors and industries, including energy, transportation, environment, poverty, natural disasters, and education. In cross-disciplinary PBL, students with various majors work together on problem finding and setting, proposing solutions, producing prototypes, and preparing presentations.

The authors launched a global PBL course in 2013 for students from Japan and Southeast Asia to develop human resources who can promote cross-disciplinary discoveries, the resolution of social issues, and innovation [7].

First, in collaboration with the Shibaura Institute of Technology (SIT) and King Mongkut's University of Technology Thonburi (KMUTT) in Thailand, a global PBL course was launched in Bangkok in February 2013, and the participants from Sepuluh Nopember Institute of Technology (ITS) in Indonesia were added to the program in the next year. The course was implemented multiple times in several years, and it resulted in many improvements, where it was applied for the eighth time

in February 2020. In addition, since 2015, KMUTT, ITS, and other universities from Japan, Thailand, Indonesia, Cambodia, Malaysia, Vietnam, Mongolia, China, Taiwan, India, Germany, the Netherlands, etc., have participated in the course in the SIT Omiya Campus in Japan. In addition, in 2017, another global PBL course was launched in Lisbon, Portugal, in cooperation among Universidade NOVA de Lisboa, SIT, and KMUTT.

The cross-cultural global PBL venues were expanded to three universities in Thailand, Japan, and Portugal as the Cross-Cultural Engineering Projects (CEPs) to be one of the modules in master's degree program of SIT's Graduate School of Science and Engineering. The main project themes are based on SDGs and various local issues in Thailand, corporate and community issues in Japan, and innovative creation in Portugal. There are differences in themes and team members in each course, however, the basic course structure for carrying out intensive activities for about 10 days is the same, and we expect the same educational effect on training global human resources.

2.2 Outline of Cross-Cultural Engineering Project at SIT

The outline of the CEP implemented at SIT Omiya Campus, Nasu Town, and Tochigi Prefecture is described in this section. It was implemented for 9 days from December 6 to 14, 2018 with 71 students and six teaching assistants who came from 21 universities in 11 countries.

Table 1. Process of the cross-cultural engineering project

Day 1	Opening Ceremony, Briefing and Ice Breaking Session Introduction of Project Themes, Assigning Groups
Day 2	Group Activities: problem identification and requirements analysis
Day 3	Group Activities: idea generation for solutions Design Review Group Activities: reflection and redesign
Day 4	Field Study and Workshop in Nasu Town
Day 5	Workshop and Group Presentation in Nasu Town
Day 6	Factory Tour at a Waste Treatment and Recycling Site
Day 7	Group Activities: building proposals or prototypes
Day 8	Group Activities: preparation for presentation Final Presentation
Day 9	Assessments Closing Ceremony

The CEP performed problem discovery, requirement definition, requirement analysis, and idea creation according to the systems engineering process, and it implemented comprehensive solution proposals (Table 1). During the course, an intermediate design review and a final presentation were held. The students gained experience in finding and solving problems and in prototyping in a multidisciplinary and multicultural environment. This experience is mainly a pre-experience of what science and engineering students may encounter in their future careers. In addition,

we introduced an environment that facilitates Internet of Things prototyping in this course. All of the CEPs were designed as PBL to promote student competency by taking into consideration the following aspects:

(1) A multinational community must be established in a short period of time;
(2) The issues must be narrowed down from the problem areas with a high degree of freedom;
(3) The viewpoint of innovation should be emphasized;
(4) Unforeseen situations similar to those in real-world projects should occur.

3 ASSESSMENT OF LEARNING OUTCOMES

3.1 Multidirectional Assessment for Learning Outcomes from the CEPs

A classification of the common learning outcomes for global human resource development was made independent of the studied subjects, where the learning outcomes corresponded to the different learning objectives of each subject, and the assessment tools were set for each learning outcome [8, 9].

The learning outcomes and tools introduced to the CEPs are the following:

(1) Generic skills (PROG applied to global talent evaluation) [10, 11];
(2) Engineering communication skills (developed a CEFR-based Can-Do list) [12];
(3) Intercultural ability.

In addition, the following two items were set in accordance with the learning objectives that are specific to each subject:

(4) Rubric for individual learning outcomes (used for student self-evaluation and student peer evaluation);
(5) Rubric for the results of the team activities (peer evaluation between teams and evaluation by teachers).

The authors reported on the engineering communication skills (CEFR-based Can-Do lists) and the intercultural abilities [12], but this paper mainly focuses on the generic skills.

The quality assurance of the educational program was achieved by analysis of the results in learning outcomes based on rubrics and a generic skill assessment test of the PROG skills) [11]. The PROG assesses competencies in working skills, personal skills, and problem-solving skills. It is one of the commonly used measurement methods introduced to 455 higher educational institutes in Japan.

3.2 Global Competency Assessment Using PROG

The PROG test was developed to evaluate “literacy” as the ability to use knowledge as a cognitive ability and “competency” as the ability to use behavioral traits and decision-making skills as noncognitive abilities. Figure 1 shows the configuration of the PROG test. The authors have seen that competency of students have been greatly increased though active learning, such as PBL, and the discussion below focuses on the competencies in the generic skills.

The PROG competencies refer to those of high-performing business people. The authors analyzed the generic skills characteristics of global human resources by measuring the competencies of business people who worked overseas and

demonstrated high performance. Figure 2 shows the average competency of (1) global business people, the Japanese people who lived in other Asian countries for 4 years on average and were highly rated, (2) highly rated domestic business people, and (3) students. The business people with management experience who lived abroad had a higher competency score than the professionals who only worked in Japan. Generally, performing in a cross-cultural workplace requires a higher degree of job performance than working in a single culture. In particular, the three characteristics of global human resources are “relating with others,” which creates good relationships with others, “team management,” which asserts opinions in one place and leads to successful teams, and “self-control,” which makes people control their stress.

Knowledge Application Ability "Literacy" (Cognitive) × Action／Decision Making Tendency "Competency" (Non-Cognitive)

Realm	Components
Problem solving skills	Collecting information
	Analyzing information
	Identifying problems
	Forming strategies

Realm	Components
Teamwork skill	Relating with others
	Collaborating with others
	Team management
Personal skills	Self control
	Self confidence
	Behavior control
Problem solving skills	Problem identification
	Planning solutions
	Implementing solutions

Fig. 1 Components of PROG

In the SIT, the PROG test was implemented for all of the first- and third-year undergraduate students and all of the first-year graduate students who were studying for a master’s degree in systems engineering and science. In addition, the PROG test was implemented for all of the participants at the completion of the Cross-CEP. To accommodate participants from other countries who do not know Japanese, English versions were available for both the PROG literacy and competency tests, and a Thai version was also available for the literacy tests. Moreover, the generic skills of all of the CEP participants were assessed, and the assessment of the learning outcomes was conducted for the students from the participating countries.

We evaluated how participation in the CEP contributed to fostering the students’ competencies. We also compared the PROG competency growth of the CEP students and the non-CEP students for the first-year master’s and third-year undergraduate students. Table 2 shows the comparison results of the first-year master’s students. In addition, we compared the increase in the competency score in the first year of undergraduate studies to the score in the first year of the master’s program or at the end of the CEP. Almost all of the competency scores have increased after students studying in the degree program with or without participation

in the CEP. Regarding the three elements of the global human resources, namely, “relating with others,” “team management,” and “self-control,” the competency scores of the CEP participants were higher than those of the other students who did not participate in the program.

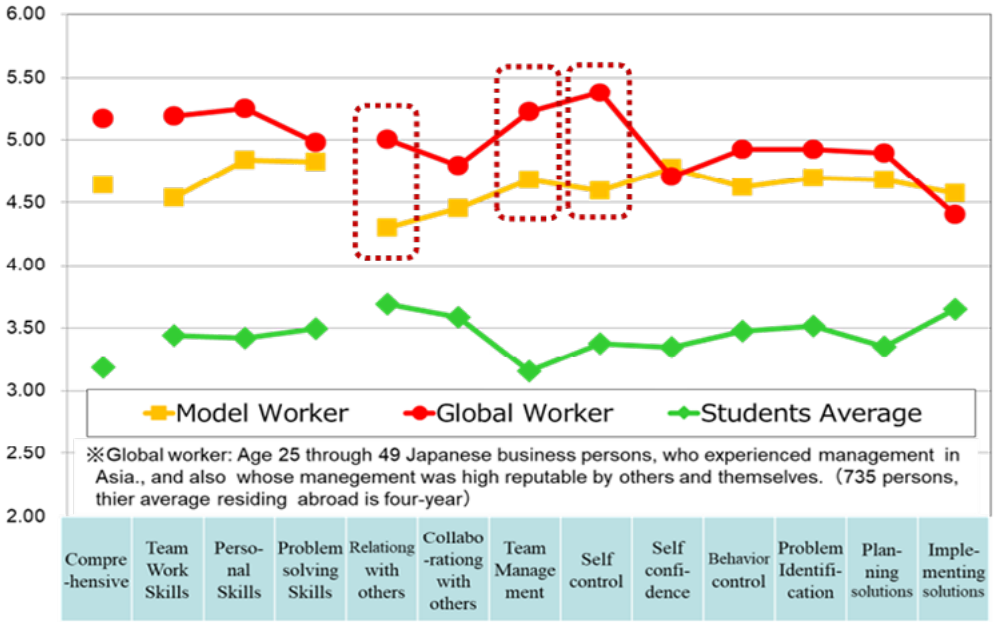

Fig. 2. Validation of PROG in competency: Comparison of global model workers, domestic model workers, and students

Table 2. Score change of firs- year graduates who took part in the CEP (change of average scores)

1st year master	1st year master of CEP(FY2018) n=16			1st year master of non-CEP(FY2018) n=48			<CEP> minus <Non-CEP> =Exceed : ✓
	1st year	1year master	difference	1st year	1st year master	difference	
Comprehensive	3.50	4.31	0.81	3.19	3.79	0.60	✓
Teamwork	3.56	4.44	0.88	3.38	3.94	0.56	✓
Relation with others	4.00	4.81	0.81	3.50	3.79	0.29	✓
Collabration with ohers	3.31	3.94	0.63	3.38	4.29	0.92	
Team management	3.50	4.63	1.13	3.21	3.75	0.54	✓
Personal	3.69	4.06	0.38	3.33	3.60	0.27	✓
Self control	3.63	4.00	0.38	3.19	3.50	0.31	✓
Self confidence	3.63	3.81	0.19	3.42	3.60	0.19	
Behavior control	3.88	4.13	0.25	3.29	3.54	0.25	
Problem solving	3.88	4.63	0.75	4.13	4.71	0.58	✓
Problem identification	4.56	4.38	-0.19	4.31	5.02	0.71	
Planing solutions	3.56	4.69	1.13	3.90	4.23	0.33	✓
Implement solutions	3.69	4.06	0.38	4.00	4.58	0.58	

Table 3 shows the results of the third-year undergraduate students. We compared the increase in the competency scores in the first year of undergraduate studies with the scores at the completion of the CEP in the third year. Almost all of the

competency scores of the CEP participants were higher than those of the other students who did not participate in the program. In addition, regarding the three elements of the global human resources, namely, “relating with others,” “team management,” and “self-control,” the competency scores of the CEP participants were higher.

The College of Systems Engineering and Science and Graduate School of Systems Engineering and Science of SIT now systematically implement many PBL programs for undergraduate and master’s programs [13], and they have the opportunity to expand the students’ competencies in degree programs. In addition, the CEP participants have generally increased their competencies in comparison with other students.

Table 3. Score change of third-year undergraduates who took part in the CEP (change of average scores)

3rd year undergraduate	3rd year students of CEP(FY2018) n=7			3rd year students of non-CEP(FY2018) n=56			<CEP> minus <Non-CEP> =Exceed : ✓
	1st year	3rd year	difference	1st year	3rd year	difference	
Comprehensive	3.43	5.00	1.57	2.96	3.30	0.34	✓
Teamwork	4.43	5.29	0.86	3.04	3.41	0.37	✓
Relation with others	4.57	5.00	0.43	3.24	3.38	0.14	✓
Collabration with ohers	4.86	4.43	-0.43	3.15	3.52	0.37	
Team management	3.71	5.57	1.86	3.00	3.55	0.55	✓
Personal	2.71	4.57	1.86	3.20	3.55	0.35	✓
Self control	2.86	5.60	2.74	3.49	3.75	0.26	✓
Self confidence	2.43	5.40	2.97	3.00	3.34	0.34	✓
Behavior control	3.43	3.71	0.29	3.09	3.55	0.46	
Problem solving	3.29	4.29	1.00	3.76	4.07	0.31	✓
Problem identification	2.86	4.29	1.43	3.89	4.27	0.38	✓
Planing solutions	3.43	3.86	0.43	3.64	3.59	-0.05	✓
Implement solutions	3.14	4.80	1.66	3.79	4.25	0.46	✓

4 CONCLUSION

In order to foster science and engineering human resources that are capable of innovation in global environments, competencies were set based on surveys conducted in Japan and overseas, and a global PBL course was designed for human resource development, which was expanded gradually in Japan and overseas. Furthermore, the system was structured by classifying the learning objectives into general-purpose learning objectives that do not depend on subjects and those that are specific to subjects, and a system for assessing the learning outcomes in multiple aspects was constructed and evaluated.

The working person competency with high performance in a global environment was evaluated in the PROG test. As a result, the three competencies, namely, “relating with others,” “team management,” and “self-control,” were identified as the characteristics of the global human resources. We also designed and introduced the

Cross-CEP to develop global competencies in undergraduate and graduate degree programs. From the evaluation results in the PROG test, it was confirmed that the CEP students had higher scores when it comes to the above-mentioned three competencies in comparison with the non-CEP students.

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A STUDY OF THE IMPACT OF DIGITALIZATION ON ENGINEERING EDUCATION INSTITUTIONS IN FRANCE

ANALYSIS OF THE ANSWERS TO THE SURVEY (FOCUS) LAUNCHED BY CTI

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Paris, France

Topics: *Future engineering skills(9), E-learning(10)*
Keywords: *digital education, impact of digitalization, distance learning*

ABSTRACT

Sometimes, when you discuss with students about their future, some of them, especially girls, say" I will study chemical engineering because I do not like computer science and data processing". In our society it is no more possible to think like this, because of the importance that data take everywhere, and so it is important to convince young people and their teachers of this evolution!

Commission des Titres d'Ingénieur (CTI) decided in February 2019 to launch an enquiry called "focus" on the practices of engineering education institutions, to make them explain to society what they did or what they are doing or going to do concerning digital education and digital processes.

This enquiry included 4 parts, and should have been answered in 4 pages by each institution:

-one part is about the pedagogic methods linked to the digital technologies developed, one of them being distance learning

-one is about teachings organized in the institution either if this institution is devoted to fields originally far from digital preoccupations, or if it is near this field

-one is about the changes in the organization of the institution linked with digital technologies

-one is about the changes in the jobs that the institution forecasts for its graduates in the next future

This enquiry had 3 major aims:

-Make institutions aware of the necessity to turn to digital teachings and processes, and for those that had already made this evolution, tell to other ones what they were doing or going to do.

-Share good practices between institutions

-Discover the evolution of jobs as anticipated by institutions

The results are quite interesting and even surprising, they concern more than 40 institutions on the 201 French institutions and we share them in this paper.

1 INTRODUCTION

1.1 Context

Many reports deal with the new jobs that engineers will have to face within 50 years and, as nobody really knows which form these jobs will have, much of the reports deal very widely with numerical skills or with the societal impact of this numerical (r)evolution, and more specifically with IA and Big Data.

The fact is that the quick evolution of both hardware and software in the last 20 years has surprised most of us, even scientists belonging to the digital community, and some algorithms that we could not apply in 1990's because of the insufficient speed of the hardware are completely usable and sometimes of very current use now.

But the influence of digitalization is much larger than those technical points. A strong shift of paradigm is taking place in the organizations too. So it is necessary to imagine Digital (r)evolution inside higher education institutions more globally.

That is why CTI, the French Accreditation Agency for Engineering Programs, after having added in 2018 a question to the data that engineering education institutions have to give it each year:" what did you put in place in the digital domain", had decided to launch a more detailed focus on these themes in 2019.

It concerned, in a mandatory way, all institutions asking for a periodic accreditation in 2019 (about 50, that is a quarter of all Engineering Education Institutions) and all the institutions that wished to answer, too.

At the end of the accreditation campaign all the results were synthetized by me as the responsible of the working group on digitalization and a communication made inside CTI and outside (in the CTI newsletter).

What can be the impact of an accreditation agency on these problematics?

We had already launched focuses on other problematics: Sustainable development, Innovation, Safety and Health at work; these were new subjects for institutions at the time when the focus was launched, and we observed that these focus had a strong effect for all the institutions because they made institutions have a deeper reflexion on those subjects.

In this specific case we were both trying to share good practices, to discover what is done and if possible, to create a dynamic of collaboration between institutions. This study is by no mean an exhaustive one, no statistics have been realized because of the great variety of the answers, however it allows us to see the trends and to communicate towards the public opinion.

1.2 Data already obtained at CTI

In June 2018, among the 201 French Schools of Engineering, representing 1047 different programs, 751 included mandatory digital education and 358 included it as optional courses [1]

New pedagogies based on digital methods were put in place in 302 programs, including use of Moodle but also of SPOCs, MOOCs, virtual classes, serious games.

What is very curious is that engineering institutions also mentioned in this field of data that they were teaching "Word". This is now taught in all disciplines, even at the secondary school, it was very strange to imagine that an engineering institution considered that this was part of the digitalization process!

During audit we could also discover more precise information on this subject, and as informatics tools were one criterion of the Eur Ace label delivery, experts already asked more precise elements on this point.

But this was not sufficient to have a global idea on the state of digitalization because, for example, chemical or agricultural engineering did not give us specific information on the field and, at this moment, no recommendations had been emitted by CTI on the field except a guideline document "Compétences en numérique de l'ingénieur" included in "Analyse et Perspective" but it was a long time ago [2].

It is the reason why the CTI's assembly decided in January 2019 that launching this focus [3] was necessary to have a real idea of things.

2 THE QUESTIONS ADRESSED IN THE FOCUS

2.1 Pedagogic innovations in link with digital

The use of digital processes is a powerful vector of pedagogic transformation that goes far away from technology; CTI is very interested in it because the evaluation of a program is not only on its content but also on the means that the institution uses to teach it, and particularly on the pedagogic innovations. Some of them need specific equipment that can be bought in common by some programs or even institutions.

The French government had previously published a very inspiring report on this subject in June 2018 [4].

For engineering especially, this is really very important because virtual teaching is very often opposed to presence teaching but there are now digital twins that make distance experimentation possible; distance learning is more and more used especially for continuing education, even if engineering often need specific organizations blending theoretical and practical education, for labs for example.

Nothing was said for the moment in our procedures about distance learning, so it was necessary for CTI to understand the actual extent of this kind of teaching, to be able to define new norms of coaching for students and to have an idea about the minimal face to face time necessary for a "good engineering education" in distance education. The coronavirus episode makes these elements more important than ever, and we can now observe that things change very quickly inside institutions: a new focus on the same subject launched next year will be very instructive.

The questions that CTI addressed to institutions were the following:

-Did the institution answered to call for projects, at national or international level, on these subjects?

-Which devices have been put in place or are being put in place at the level of the institution, of the site, or of the network to which the institution belongs?

-Which good practices could be shared?

-How the impact on quality of apprenticeship of the students with these new actions or devices can be measured?

All these questions were rather general but CTI wanted to get a broad view on those practices because very different fields are covered under the name pedagogy. For example, Learning Analytics can be as well considered as a pedagogic innovation as a change in organisation.

2.2 Content of the curricula

All the same disciplines cannot be taught in Chemical engineering, in Agro sciences Engineering and in Computer Science Engineering. That is the reason why CTI asked the institution to precise the fields of the programs taught.

The analysis and report made by CTI after reception of the information of the institutions had to be presented according to these two categories:

-Programs outside the field of digital engineering

-Programs in the field of digital engineering

This classification is sometimes a little subtle because for example Geology is not in the field of digitalisation but Geomatics is.

From programming to automatic apprenticeship, through datamining, cyber defence and AI, all activities should have been described with the corresponding durations and the levels of teaching.

Are those teachings directly linked to the evolution of the program in terms of new job opportunities? was a question of interest.

How these teachings are integrated in the program and are complementary to traditional teachings? was another interrogation.

Which activities supporting those teachings have been put in place? from conferences to projects, numerous modalities are possible depending on the student's level concerned by the curriculum.

Another aspect which is of great interest to CTI is the societal impact of this digitalisation. It must not be underestimated: institutions are invited to explain how they introduce this subject with their students.

2.3 Changes in organizations linked to digital

As told in the ministry report [4], digitalization can lead to a global transformation of the organisation of the institution. To introduce digitalization, it is not sufficient to buy an ERP or a sophisticated software and digitalization goes far beyond the use of such devices.

The institution had to describe digital tools or organisations already put in place and the new tools that will be in place in the future. This must be done at the local level, at the network level or at the site level.

The social climate of an institution can be impacted by these evolutions: how does the institution act to take into account this phenomenon?

2.4 Changes in the job graduates will occupy

Even if Pole Emploi, the French agency for jobs, has published a report on these changes [5], few documents have been published on the evolution of jobs and functions. It seems to CTI that institutions have to realize a study of those evolutions for example putting in place an observatory, or realising a technology watch or working with the professional associations.

But this is not enough the case, it is no more possible to continue saying that nobody knows the future of engineers' job, because students and their parents have to know, but also because those new attractive jobs with new forms of employment could be

more attractive to the new generation than the older jobs and so, it could globally contribute to the attractiveness of engineering education.

2.5 Global evaluation made by the institution

The institution is invited to give details on what is its future, what is easy or difficult to put in place, and on the conduct or modification of its strategic plan.

This part was also very important because it could indicate generic difficulties that institutions had to face and which solutions could be brought by the accreditation agency.

The institution has the necessity from time to time to have a glance on itself and on its practices, so the end of the focus consists in the analysis that the institution has, on its involvement in the four dimensions (previously described) of this digital (r)evolutions, for example:

Does it change something on the employability of the graduates?

Does the institution think it has still to progress in the field?

3 THE ANSWERS OF INSTITUTIONS

The amount of answers was a surprise for us: some institution wrote 32 pages instead of the 4 pages that where asked because they had previously defined their strategic plan on digitalization and wanted to explain it because they were proud of it.

All institutions wanted to share their best practices, and very few of them had done nothing: some were more concentrated in distance learning, some were more focused on new disciplines for the future.

But the more interesting and surprising effect is the site effect, more important than the network effect: in a specific place (Toulouse for example, or Lyon), the Region can create a dynamic through collective actions or specific calls for projects that all institutions (private or public) follow, whatever the field of their discipline is and whatever the network they belong.

The third point is the weakness of evaluation of those new practices for the moment. In France the idea of making research on human factors inside Engineering Higher Education Institutions is something new and so not enough developed for the time being, so it is difficult to realise very pertinent studies on those evaluations.

3.1 On pedagogic practices

This field was the more developed by institutions and was a real shock for us because as distance learning is never indicated by institutions in their accreditation file, we did not know that distance learning was already existing in France. But this did not mean that institutions did not do it: they only did not tell us!

Nearly all of them have developed even through Moodle some distance education in a form more or less sophisticated. It makes CTI more obliged to define quality norms for this kind of education that was ignored by CTI till now.

Under the idea of pedagogic innovation, we meet very diverse answers in their level of abstraction: some are in link with evaluation of learning outcomes through portfolios, some institutions are also using these new opportunities to begin a reflexion on the new role of their teachers.

Use of virtual reality and digitalization of labs are something quite specific to science and technologies and few schools are making experiments in this domain because a serious investment is needed. Those institutions that do it have very often obtained the money necessary through calls for projects.

Many schools have answered to call for projects, regional or national ones but less on the international level. The specific call named IDEFI that had pedagogic aims is very often quoted. Inside Universities a Bonus (that is a specific gift of money) was organized on the form of a call project and many new devices were bought thanks to it.

This new experiments very often apply to distant publics (Africa for example) or to continuing education students but also to “prevented students”. Sometimes distance learning is realised in addition to standard education.

Something very interesting was presented by several schools: the use of new pedagogies to attract high school pupils through MOOCs for example, these MOOCs can be realized by students, if the institution has the infrastructure to realize its own MOOCs.

Many institutions have adapted their informatics networks to be fitted with Bring Your Own Device and some even bought digital tablets to all their students.

We also observe a real interest to “Learning Analytics” some school already experimenting it for a specific part of their students, other one having the strong purpose to invest in it soon.

3.2 On what is taught in the programs

Something is common for all engineering institutions, time devoted to teach data analysis, it seems that more and more engineers of all fields become also data scientists

-for institutions in the field of digitalization: cybersecurity, IoT, Big Data are the items that come more frequently; and less frequently come AI and machine learning

Few information is given on the amount of hours dedicated to those teachings and too few school develop precisely what they teach concerning the human impact of digitalization but very often appears the teaching of the management of change or of digital transition in factories. Some institutions are very concerned by data protection not only in their organisation but also in their teachings.

-for other institutions not in the field of digitalization: tools of modelling or simulation are the most important item, but also embedded systems; BIM, all what concerns Factory of the Future, and bioinformatics, Geographic Information Systems, or cyber physic systems are taught in the schools devoted to those sectors.

More surprising for us was the fact that life sciences have drastically changed their teaching to fit with the digitalization.

The general idea is that institutions really saw the digitalization as a change of paradigm on data more than introduction of new tools, and they managed the evolution of their programs consequently.

3.3 On Organisation and management of the institution

In France there is a real problem at this moment to find the good software for the management of a big education institution.

The French state had elaborated software for management of students and teachers that revealed not to be very performant (Cocktail) and it was difficult for a public institution to escape those tools.

But there are many initiatives to manage Learning outcomes by portfolio, to manage Alumni through social networks, to manage skills of students recruited…

But moreover, institutions want to produce indicators of satisfaction of students and teachers. This preoccupation for quality joins the preoccupation of evaluation agency on this field and we will have to build criteria together.

We observe that many people have been devoted to the management of digitalization inside the institutions, in the aim of increasing service to users.

GDPR appears to be also a problem taken very seriously by institutions and the choice of software tools sure enough to manage the security of system worries institutions.

3.4 On Jobs Evolution

Programs in computer science or software have been put in place to answer the demand on system security and data analytics.

Data scientist are needed in every field of activity but also specialists in Geographic information Systems.

Global managers of digital systems are needed such as Chief Digital Officers, they can be educated through our generalist engineering departments.

Some institutions have or will put in place a council for prospective especially in health engineering or agriculture engineering, BIM is also developing very quickly as well as jobs for Industry 4.0, “data and mobility” can also be a challenge for the future of jobs.

Institutions insist on this digital transformation, so they are preparing graduates able to adapt, this is the main result of this enquiry.

3.5 On the lessons that institution take

Institution regret that they do not have good indicators to measure the apprenticeship of their students in the use of their new tools. Many schools are interested by Learning Analytics.

Some institutions that did not have this digitalization in their strategic plan are reorganizing their strategic plan just now.

But everyone insists on the necessity to make teachers and staff evolve strongly as well as students and on the fact that digitalization changes states of mind.

It is very curious that no institution spoke of the difficulties for student to access to distance learning which was something very developed in the answers of students to similar enquiries. This show that it is necessary to compare the results of these focuses to the answers obtained among students!

4 CONCLUSION

A focus is not enough to make situation evolve, it is necessary to broadcast very largely its results, this was foreseen, but the Covid 19 makes all plans change, as well those of institutions as those of the accreditation agency!

A debate on distance learning has been realised by CTI in June after the presentation of the analysis of the results of the focus on this dimension through the CTI newsletter: schools are waiting the evolution of our criteria especially those concerning teaching to prevented people.

Another focus on the same theme will be launched next year and the results compared to the result of this year, so it will be easy to discover the importance of real situations such as Covid 19 on the evolution of practices. They are perhaps better boosters than an evaluation agency!

On a more general point of view, the answers show that institutions have well understood the importance of this digital (r)evolution, more than tools it is a real change in minds that is prepared by HEIs, but with the constant preoccupation that student and staff follow the evolution.

Institutions also have questions such as apprenticeship efficiency: they should turn to pedagogic science and psychologists of education to be able to get the good answers.

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MAIN OUTCOMES OF HEIBUS PROJECT AND FUTURE COOPERATION OF ITS PARTNERS

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Conference Key Areas: *Interdisciplinary education, HE & Business, Career support*
Keywords: *Multidisciplinary, international, innovation, flexible mentoring*

ABSTRACT

Smart HEI-Business collaboration for skills and competitiveness (HEIBus) was Erasmus + Knowledge Alliances 2 (KA2) project with a budget of about one million euros and a duration of 36 months (1 January 2017 – 31 December 2019). The project focused on strengthening the collaboration between HEIs (High Education Institutions) and companies by developing and testing new, smart and innovative cooperation models for HEI-company cooperation and methods for teaching. The project brought together HEIs and companies from five European countries with strong expertise and experience in different fields. These models and methods facilitated the involvement of students, HEI educators and company experts in international and multidisciplinary Research & Development & Innovation (R&D&I) projects proposed by companies.

During HEIBus project all HEI and company partners worked hard and took part intensively in all their own project activities. All goals of the project were achieved very well and some of them were even exceeded, for example one extra Multidisciplinary Real Life Problem Solving project was carried out. After the project all partners are really satisfy for the outcomes and want to continue, deepen and widen cooperation.

During the Coronavirus pandemic it has been very clearly noticed how important it is to use effectively virtual methods which were a lot tested and practised in this project.

1 BASIC INFORMATION OF THE HEIBUS PROJECT

1.1 Aims of the HEIBus project

It is important that the needs of working life are matched with the education provided. This is an ongoing process and can only be reached with continuing and fluent HEI-company cooperation.

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The aim of the Smart HEI-Business collaboration for skills and competitiveness (HEIBus, www.heibus.eu) project was to increase, improve, widen and deepen HEI-company cooperation at the student and the expert levels, promoting innovation, flexibility and entrepreneurial thinking.
The project focused on strengthening and deepening the collaboration between HEIs and companies by creating new innovative cooperation models. These models facilitated the involvement of students and educators of HEIs and experts of companies in international Research & Development & Innovation (R&D&I) projects proposed by companies.

1.2 Partners

The HEIBus project consisted of five university partners and seven company partners from five different European countries (Finland, Germany, Hungary, Romania and Spain) as full partners:

- JAMK University of Applied Sciences (JAMK, main partner, www.jamk.fi/en/) and ITAB Finland Oy (www.itab.fi/en/) from Finland
- Technical University of Cluj-Napoca (TUCLUJ, www.utcluj.ro/en/), SC PRO Tehnic (www.pro-tehnic.ro) and Automates ACM SRL (www.automatesacm.ro) from Romania
- University of Miskolc (ME, www.uni-miskolc.hu/en/), Electrolux (www.electrolux.com) and Robert Bosch Power Tool (www.bosch-garden.com/gb/en) from Hungary
- University of Applied Sciences Esslingen (HE, www.hs-esslingen.de/en/) and Stoebich (www.stoebich.com) from Germany
- University of Jaen (UJA, www.ujaen.es/serv/vicint/home/index) and Valeo Lighting Systems (www.valeo.com/en) from Spain.

The group of partners consisted of SMEs as well as some large companies. Three HEI partners were academic universities while two were universities of applied sciences. The partnership comprised a perfect variety of different types of organisations and professionals. This provided very interesting and fruitful cooperation with different perspectives on each aspect of the project. Also 17 associated partner companies and institutions and several external partners around Europe followed the progress, utilised the results or took part in some of the project activities.

1.3 Work packages

In HEIBus project there were 8 work packages which are Management (WP1), Best practices of HEI-company cooperation (WP2), Multidisciplinary Real Life Problem Solving (WP3), Expert Level Real Life Problem Solving (WP4), Flexible Student Mentoring by Companies (WP5), Quality Assurance (WP6), Evaluation (WP7) and Dissemination & Exploitation (WP8). Four of them (WP2, WP3, WP4 and WP5) were implementation work packages which will be explained deeper in the following chapters.

2 METHODOLOGY

Cooperation between HEIs and companies is not a new concept. There are cooperation programmes, which date back to the first decade of the 20th century [1] or are well-known internationally that have served as a reference model [2].
In HEIBus project the methodology shown in *Fig. 1* was implemented with the aim to identify and analyze the existing cooperation models around the world providing real life experiences between HEIs and companies.

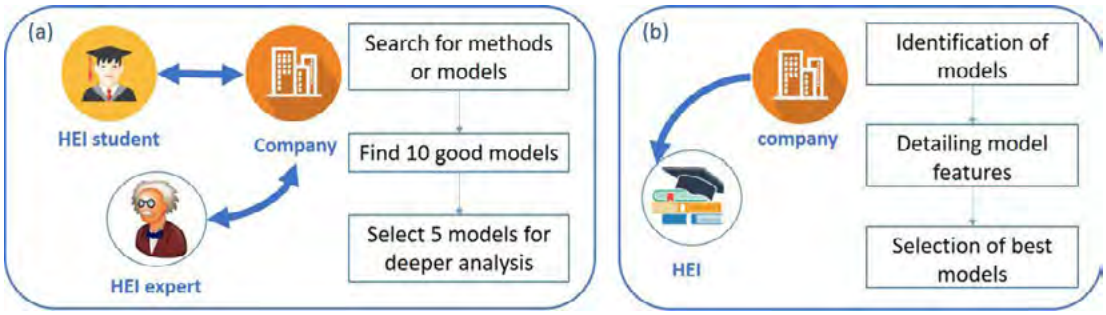

Fig. 1. Methodologies to identify the best exiting models of HEI-company cooperation. (a) Interaction between HEI student and HEI expert with company; (b) Company involvement in HEI education

As can be seen, the analyses of HEI and company cooperation models follow the same procedure (*Fig. 1a*) with the exception of the analysis of company involvement in HEI education (*Fig. 1b*).
In the Best Practices of HEI-Company Cooperation work package (WP2) it was carried out the idenfification and analyzing of the existing cooperation models providing real-life experiences between HEIs and companies in the following way:

- to analyse the state-of-the-art HEI student-company cooperation models
- to analyse the state-of-the-art HEI expert-company cooperation models
- to analyse different platforms and forums used in HEI-company communication
- to analyse the best practices on company involvement in HEI education.

Descriptions of existing cooperation models and the main WP2 tasks are in *Table 1*.

Table 1. Existing cooperation models and the main tasks of work package 2

Student-company cooperation models	**HEI expert-company cooperation models**	**Internet based platforms for HEI-company communication**	**Company involvement in HEI education models**	**Coaching for virtual activities**
To search different existing methods or models	To search existing models	To find and analyse 15 internet based platforms	To search different existing methods or models	To ensure effective participation of all partners in virtual activities
To find at least 10 good and beneficial models	To find at least 10 good and beneficial models	To search best practices for communication	To search different levels of involvement	To organizes coaching of virtual methods

To select 5 models for deeper analysis	To select 5 models for deeper analysis	To build a new platform or to join in best available platform	To analyse different levels of involvement	To use social media for different project activities
To form background for the Multidisciplinary student level real life problem solving (WP3)	To form background for the Expert level real life problem solving (WP4)	To help continuation of the HEIBus activities after the project	To form background for the Flexible student mentoring by companies (WP5)	To invite associated partners to take part in virtual coaching

Work package leaders searched existing methods and models for HEI-company cooperation and they selected the best models for deeper analyses [3]. Regarding the outcomes of this work package, the common opinion of HEIBus partners was that the best and most comprehensive ideas and models for HEI-company cooperation were found. These models formed a good background for the other implementation work packages, WP3-WP5, which are introduced in the next chapert.

3 IMPLEMENTATION, RESULTS AND FEEDBACKS OF HEIBUS MODELS

The HEIBus project developed its own specific models for each of the former ways of cooperation. Following sub-sections present a brief overview of these models and also the main results and feedbacks of the implementations. Detailed descriptions can be found in [4] and [5].

3.1 Multidisciplinary Real Life Problem Solving (RLPS, WP3)

The idea of RLPS model was that students from different study programs and nationalities formed three mixed, international and multidisciplinary groups in other to solve a real-life problem proposed by the project company and to compete each other. *Fig. 3* shows a diagram of the RLPS model.

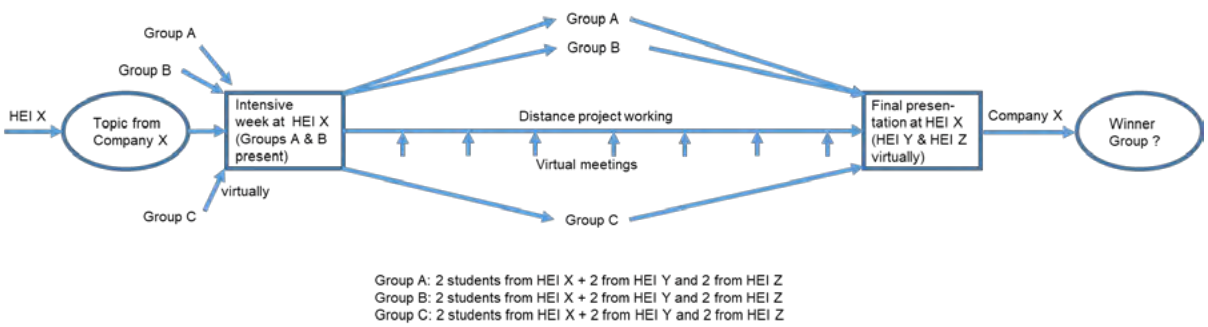

Fig. 3. RLPS model

The project started with an intensive week, hosted by the HEI whose company partner offered the topic. During this week, two international student groups had face-to-face meetings while the third group had them in a virtual way. After the intensive week, all three groups worked virtually and were supervised by the

company tutors and the HEI supervisors. At the end of the project, the company tutors selected a winning solution and group and HEI supervisors evaluated students.
During the intensive week it is very important to focus on the tailored lectures and to explain what the students really need to know from the specific task. There is no added value for example to explain random company information which only takes away the precious time needed for team work. Good English language skill level is needed for all participants: students, HEI supervisors and company tutors.
Advanced computer program(s) and good meeting equipments, for example a meeting microphone and a webcam, and also a suitable and silent meeting place are needed to have in every participating HEI. It is also very important to have guidance In the beginning of every RLPS project, HEI supervisors had a meeting with students where they explained how to use right and effectively needed equipments.
After six original RLPS projects, collected feedbacks showed that many students and supervisors would have appreciated another intensive week. The 7th RLPS project included another intensive week in the middle of the project period. The opinion of students and supervisors was that this modified version of RLPS was very good and workable. All feedback surveys showed that the implementation way of RLPS projects was very innovative way to study and extremely useful for their future. All HEI supervisors and company tutors mentioned that RLPS projects should definitely be continued on the created and tested ways in the future, too.
It has been interesting and rewarding to read the success stories of students who have found internship, final thesis and/or permanent work place at the project company after taking part in RLPS project.

3.2 Expert Level Real Life Problem Solving (EXPERT, WP4)

In the EXPERT project, the project company gave a more complex problem than in the RLPS project which a group of international and multidisciplinary experts of three HEIs solved together with the company experts, see *Fig. 4*.

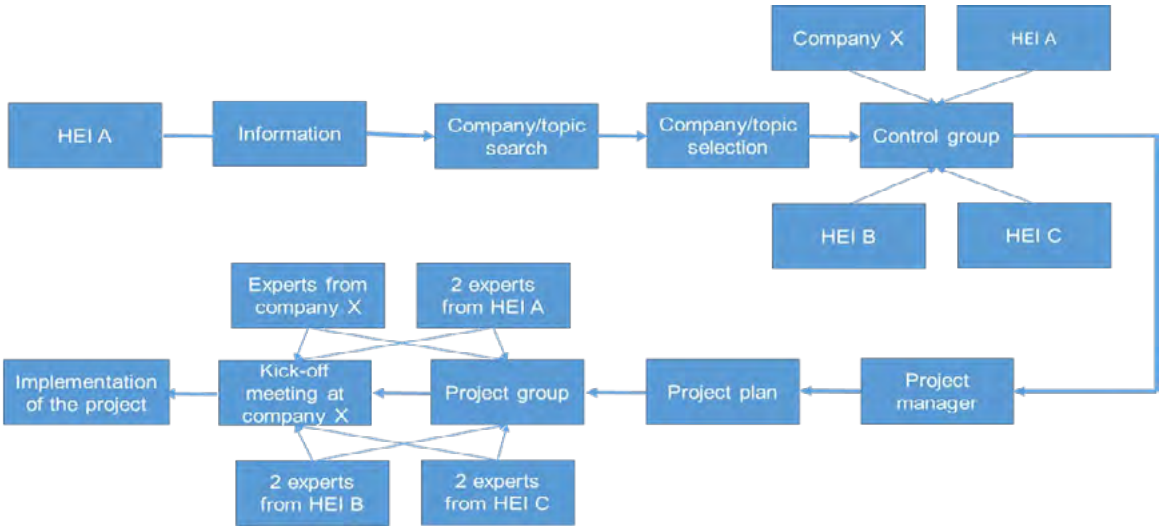

Fig. 4. EXPERT model

The EXPERT project started with face-to-face kick-off days hosted by the HEI, whose company partner offered the topic. The kick-off days contained a visit at the project company and team working sessions at the host HEI. Then, about four month time, the experts worked at their own HEIsand the company, meet each other only in virtual meetings and finalised the project.
The feedback surveys showed that EXPERT model promoted innovation and knowledge transfer between HEIs and companies as well as increased the skills of the HEI experts and the working life relevance of education.
EXPERT projects offered the opportunity for HEI experts from three countries to collaborate closely with company experts in a joint research project with direct impact in everyday life of the company. EXPERT projects helped HEI experts in increasing their know-how of the work field with great potential of implementing the new info in the teaching materials. In the same time close connection with the company helped to create an international network of experts and to find new topics for future projects. EXPERT model seems to be very good and suitable for the demanding international projects.
The EXPERT work package also included the building of a virtual Expert Support Service (ESS, www.heibus.eu/experts), which allows easy and quick access for all companies looking for expert services by HEIs. The ESS offers direct expert contacts for starting an EXPERT project and possibility to ask quick support for smaller problems.

3.3 Flexible Student Mentoring by Companies (Flex Mentoring, WP5)

The HEIBus project tested flexible ways to involve companies in the education process of students. Each HEI and company chose the involvement level and method best suited to them. Flexibility came from the different levels of involvement. The most common and used methods were: tailored lectures, supervision of projects and laboratory work and dedicated courses given by company mentors, visits and trainings at companies and also workshops, seminars and fairs, where students cooperated with company representatives.
The company mentors acted as godparents for a certain student group and in the same time they had possibility to do long-lasting recruiting and to find the most suitable students and future engineers for their needs.
The commitment of company mentors and students is important for the whole project period. Fluent communication between company mentors and students is essential and it helps to maintain the high motivation for everyone. It is also important to find a suitable company for a certain student group.
The main outcomes of Flexible Mentoring projects were increased motivation and study success for students, easy recruitment and a good labour force for companies and good knowledge transfer between HEIs and companies.

4 OUTCOMES AND KNOWLEDGE TRANSFER

4.1 Main outcomes of HEIBus

During the kick-off meeting of the HEIBus project the main contact persons of all partners got info and supervision for effective virtual meeting arrangements and they practiced together how to use needed equipments. These main contact persons were the key persons for supervising other staff members and students at their own organisations to use the equipments of virtual meetings. This guarantees that after the HEIBus project it is easy for all partners to carry out virtual meetings.
Experiences of the totally and partly virtual RLPS and partly virtual EXPERT projects have been very important to share and spread worldwide especially during the time of crisis such as Coronavirus pandemic. Online meetings, teaching, supervising and mentoring have become the new normal, so collected and shared experiences of the HEIBus project are valuable for everyone.
The feedback surveys of RLPS projects showed that the common opinion of students, HEI supervisors and company tutors was that these projects were successful, rewarding and very innovative way to study and cooperate. All students informed that they also came more international and improved their English language skill.
The feedback surveys of EXPERT projects showed that all HEI and company experts found these projects excellent, effective and innovative way to cooperate and solve complicated problems. In the same time HEI experts increased their knowledge of the project company and company experts their knowledge of three international HEIs. All experts informed that they want definitely take part in new EXPERT projects in the future.
The HEIBus models have their own distinguished features. Because the HEIBus was an international project, features such as multilingual, multidisciplinary and virtual work were included in all its implementations and made them unique.
Three HEIBus models and outcomes of their implementations have been introduced in several national and international conference publications and presentations, professional articles, TV and radio interviews which can be found at HEIBus web site. HEIBus partners are continuing cooperation and implementations of all three cooperation models. Here some examples:

- Finnish and German HEI partners together decided to implement a tailored RLPS project in every academic year by financial help of own HEIs and other HEI partners are planning to continue RLPS projects one way or another
- HEI partners are together searching new possible ways to carry out RLPS and EXPERT projects without EU grant
- All companies can use the virtual Expert Support Service (ESS) to find the best and most suitable HEI experts for their needs
- HEI partners are continuing to carry out Flexible Mentoring projects with the company partners they cooperated during HEIBus project
- HEI partners introduce and invite new company partners for Flexible Mentoring projects

This means that in the future there will come new outcomes and be created new publications which can be found at HEIBus web site. In the future the dissemination of HEIBus outcomes will continue and widen in the educational field.

4.2 Knowledge transfer after the HEIBus project

At the HEIBus web site (www.heibus.eu) under Intellectual Outputs – Public Project Reports there is "RLPS Implementation Guide" where can be found for example Step-by-Step-Guide, Checklist and Model of Intensive Week reports. There are also "Process model for international expert cooperation", "Information sheet about international expert cooperation" and "Info materials for Flex Mentoring program" reports. These reports consist a lot important and valuable information and make it easy for new HEIs and companies to copy these three models and carry out new RLPS, EXPERT and Flex Mentoring projects themselves.
During the HEIBus project HEI partners also cooperated with new international cooperation partners and took part in the application work of new international projects which at least partly base on the HEIBus cooperation models. Some of the proposals have already accepted and projects have started, for example the EIT Raw Materials project (https://eitrawmaterials.eu) and Erasmus ICM project between University of Miskolc (ME, Hungary) and University Guru Nanak Dev (India). Three HEI partners (JAMK, TUCLUJ and UJA) took part in the application work of a new Knowledge Alliances 2 (KA2) project and got the positive feedback from EU in the end of July 2020. The name of this project is Processing Complexity with Emotional, Sensorial and Spiritual Capacities (ProCESS) and its main HEI partner is Catholic University of Lyon (France). The ProCESS project will start in the end of year 2020.
All three HEIBus project models will be introduced and published later this year as good and innovative cooperation examples in the Circular Economy Competence of Universities of Applied Sciences project funded by the Finnish Ministry of Education and Culture (https://kiertotalousamk.turkuamk.fi/kiertotalousamk/).
HEIBus partners will further create professional and scientific papers of HEIBus models and project outcomes for national and international conferences. All accepted papers and new outcomes can be found at HEIBus web site in the future.

5 SUMMARY

Based on the best practices of HEI-company cooperation, it can be concluded that the HEIBus project created innovative models for HEI student-company and HEI expert-company cooperation. Features such as: multilingual, multidisciplinary, international, innovative, virtual team work, applicability of student evaluated by the company are included, all together, in the HEIBus models. Implementations of HEIBus project were effective ways of strengthening and widening the collaboration among all HEI and company partners. Feedbacks of all partners were very positive and they learned a lot from each other and from new kinds of cooperation. All partners want to continue, widen and deepen cooperation, which was one goal of the project.

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CASE: TELEPRESENCE ROBOT – VIRTUAL, BUT ACTIVELY PRESENT TEACHER IN A PROTOTYPE LABORATORY

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Conference Key Areas: *E-learning, blended learning, virtual reality*

Keywords: *Telepresence robot, prototype laboratories*

ABSTRACT

Nowadays, globalization is actively present in higher education. It includes global mobility of both people and knowledge. Research groups are international, and the mobility of students and teachers is continuously increasing. Technology enables us to interact over distances. This is good for the development of science and humanity. Impending climate change forces us to seriously think about the climate impact of air

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travel, for example. Meetings and lectures can quite easily be arranged virtually, but work done in laboratories usually requires an on-site teacher.
In this paper we present a case of building and testing a telepresence robot at the protolaboratory J. Hyneman Center at LUT university, Finland. There are several commercial telepresence robot manufacturers, and devices are produced for various needs, e.g. working in hazardous environments. We are building a relatively simple telepresence robot that can act as a substitute or a kind of an avatar for a physically distant teacher in a prototype laboratory. This device is built as a student project by using common and inexpensive components.
The aim of the paper is 1) to present briefly the building process of the device and 2) to present the first user experiences of the device in a prototype laboratory environment, from the standpoint of the both students and teachers. We also discuss the pros and cons of this kind of telepresence-related co-creation in engineering education. By doing so, we prove that the era of telepresence teaching in laboratories has already begun.

1. INTRODUCTION

Nowadays, higher education in universities is a global activity for which the free movement of both people and especially knowledge is important. Research groups are international and likewise, in education it is becoming more common for students to go on international exchanges as well as for researchers and teachers to work for periods of different lengths abroad [1]. However, short commutes, especially by air, put a strain on the climate and also incur costs, which in some cases can limit the flow of people and thus, information and knowledge. There are also other limitations that may prevent, for example, visiting lecturers and teachers to travel, like in 2020, when a pandemic stopped passenger traffic quite efficiently from around the world [2]. However, work in universities did not stop since technology enables us to interact over distances and continue research, teaching and learning. Meetings, lectures and many courses can easily be arranged in a virtual form. Laboratory work which is essential in many technical disciplines [3], is, however, more difficult to organize without an on-site teacher or instructor, and while verbal communication can relay content or instruction, the lack of a mobile physical presence of the instructor by only presenting a video image of them on a screen potentially limits the impact of the interaction with a student. Simple video conference calls have been common for a number of years but are generally accepted as inferior to in person meetings. Our proposition is that it would be preferable to enhance such interactions with a telepresence robot which has been engineered to replicate as much as is practical a person to person interaction.

Traditionally, university education has relied on lectures and training tasks that support them. In addition, there is often laboratory teaching in the technical disciplines. Often students work in laboratory on their own, but with the assistance of a teacher. In basic courses, laboratory work is usually planned in advance and it is up to the students to complete them in accordance with the instructions and data provided. Advanced courses give students more responsibility and can plan their laboratory work more on their own. In prototype laboratories, students work mostly

independently, but sometimes advice and comments from the teacher are still needed, especially when facing ill-defined and/or open-ended problems. This requires the presence of a teacher in the laboratory.

Sometimes the best expert can be far away from the university campus, even on another continent. Today, it is not always necessary to travel: virtual lectures and remote connections are already common and the COVID-19 epidemic boosted their use even more. In laboratory conditions, however, the mere presence on the computer screen may not be sufficient. In order to teach and guide effectively, the teacher should be able to move around the laboratory. In this case, the telepresence robot [4] can be of great help if it has enough human like functionality that the student starts to interact with it as they would a with a person.

The telepresence robot does not function like some programmed robots which would require at least some artificial intelligence, i.e. the aim is not to help at some routine tasks, such as safety and lab instructions, answering the same type of questions over and over, monitoring students at work etc. Actually, it is a camera eye and robot arm connected to microphone, loudspeaker and moveable platform – all controlled remotely. The tool that wakes up to work only when someone remotely connects to it and starts using it. Several visiting teachers can use the same tool, and naturally, the knowledge of a robot thus depends a lot on the skills of the person using it. Naturally, students can ask questions via a robot to the person accompanying them, and when the person is elsewhere, the questions must also be asked in other ways, such as by e-mail.

Therefore, the discussion about pros and cons of the telepresence robot could be similar like discussion about some virtual meeting tool; what things we want to do with the tool, how they could be implemented technically, and what kind of guidelines are needed for both the teacher and the students to use it. An important consideration is also the potential misuse of the tool; are there unethical ways to use telepresence robots in an educational setting and how could they be prevented? When telepresence devices become more common, general rules for their use are also needed.

A group of students started building this kind of a telepresence robot, an avatar for a visiting teacher, in the protolab. This concept paper outlines how a robotics project can be introduced to help students understand all aspects of design, implementation and operation.

2. METHODOLOGY

The telepresence robot project was built by student teams as an exercise for “Processing of Analog Signals”, “Electronics Project Work”, “System Engineering Project Work” and “Technical Design” courses of mechanical engineering and electrical engineering departments. In this case, the staff of the protolab acts as the robot's supervisor and defines the necessary functions, as well as monitors the progress of the work together with the course teachers. Since the telepresence robot project is experimental, it will have continuous development and hands-on testing, and the project will be ongoing even as student groups will change. It will be

motivating for student teams to build on top of each other's work on building and testing the robot.
The project will teach students - and teachers, too - to collaborate between different disciplines, and will provide hands-on experience of project work with meetings, testing, and different perspectives, all of which must be considered to build a working telepresence robot. It also teaches how to clarify work-related issues from previous factors, similar to documenting and guiding groups of students who will continue to work after the previous builders.
Another telepresence robot was built at the same time in M5 industries, San Francisco, and in this way, the university students were able to exchange experiences and thoughts with M5 industries group, and for example, try and learn what it's like to control a robot on another continent.

2.1. Definitions (what a robot should be able to do)

The idea was that a student team would build the first version of the telepresence device to be very modular and flexible, and do it with a relatively small budget. This was to prove that the concept works, and the plan would be to create a successive version of the device based on the learning experiences from the first one. The requirements for a telepresence robot were defined for the student team from the perspective of a client. In this case, the main consideration for re-examining the requirements to create a functioning robot was left to the student team.

The main operating environment of the device will be a proto workshop, so the area will be about 330m^2, consisting mainly of worktables and some manufacturing equipment in the larger space, and smaller workshops behind closed doors. The operating environment of the device effects the requirements and it needs to be able to move outside its main operating environment as well, although it will need to maintain an internet connection in order to be remote controlled.

*2.1.1 **Robot arm***

The user of the telepresence device should be able to communicate and operate in a proto-workshop environment. A requirement is that the device should be able to see what is happening on the working tables, look at something on the floor, or face someone eye to eye. In addition to seeing, the telepresence device must be able to point things out and grasp objects, and all robot movements and functions must be remotely controllable.

*2.1.2 **Audiovisual***

The most important feature the robot should have is that the operator of the device should have good, clear camera image in order to distinguish details from the prototypes and work which it will guide. If bandwidth is limited, devices might transmit data from only one camera, at the cost of lacking the depth perception achievable from stereo vision, or software could be designed to minimize bandwidth requirements but assigning areas like faces or center of frame to have higher definition, or not refreshing areas that are not changing.

The user of the telepresence device must hear the sounds around the device as if he were physically present, so multiple microphones might be needed. The user must be able to communicate by voice transmission, and the sound quality should be sufficient to make the speech very clear.

2.1.3 Movement

The telepresence robot must be able to go through normal doors, about 90 cm wide. It would also need to be able to go down typical aisles in a classroom or lab. University facilities are often maze-like and have many doors. However, the robot would not need to be able to open the doors itself if there is a human assistant made available to accompany it. Opening the door will be excluded from the initial requirements as it is considered a demanding operation and it would complicate the construction of the first robot too much. The robot should also fit in the elevators together with a guardian though, and it would not be too much to expect it to be able to push buttons or switches, such that if the facility is equipped with automatic doors it could move through them and operate elevators.

2.1.4 Basics and safety

The device must be rechargeable. The remote user does not need to be able to do this in the first iteration of the robot, as it is enough that a physically present guardian is able to do this without special training. The battery should last for at least about two hours of normal operation. The telepresence device must independently prevent collisions with, for example, pedestrians, glass doors and the like. A more comprehensive security arrangement was not included in this version as it is used under controlled conditions in the presence of persons. Successive iterations might benefit from 360 degree cameras or special purpose cameras that are able to clearly spot any potential collisions, not to mention using geo fencing to inhibit remote operators from making the robot go places it is not wanted.

2.2. Robot design and construction

The robotic system includes several components as shown in Fig. 1: a camera, a main processor for video processing and wireless communication, speakers for remote user audio, an embedded auxiliary processor (traction motor control), a manipulator arm, and batteries and required peripherals such as indicator lights. The following sections introduce these different aspects of the project [5].

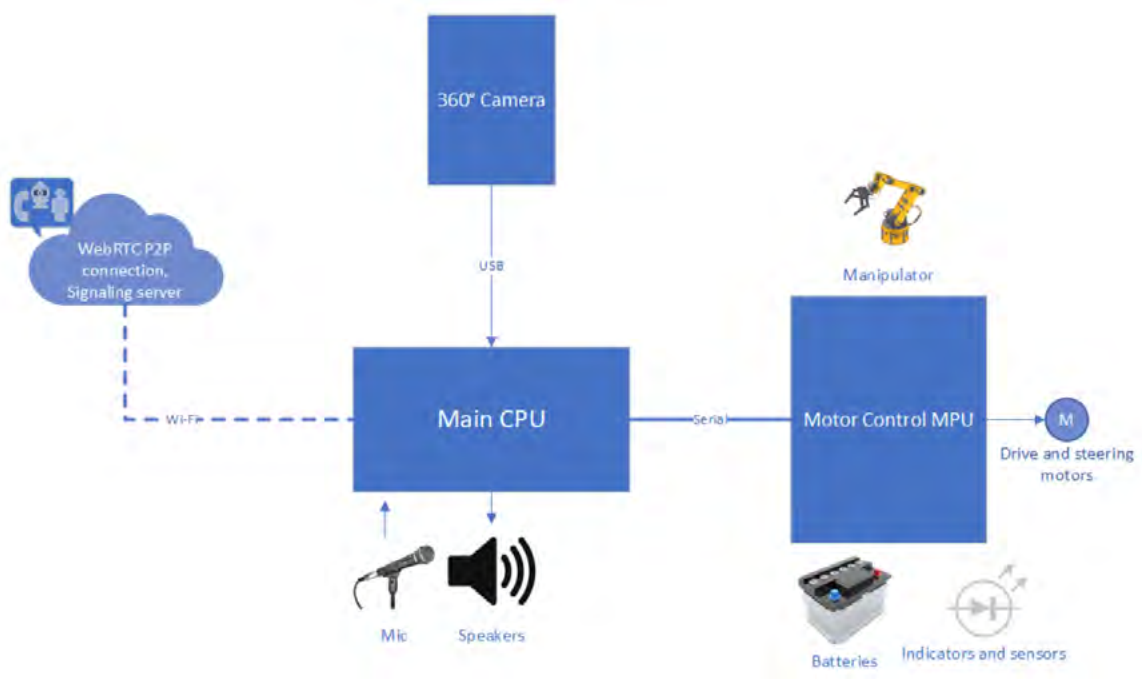

Fig. 1. Simplified block chart of the telepresence robot system [5].

2.2.1. Robot arm

The BCN3D MOVEO was chosen as the robot hand. The most important requirements of the hand are the dimension of about a meter and the possibility to lift an object weighing a kilogram. Transmitting the robot arm position to a remote user via a 2D camera is not easy, due to the six controllable axes, therefore controlling the hand intuitively will be challenging.
It is possible to simulate the trajectories of the hand in advance and it would be possible to transfer these simulated trajectories to the hand via Arduino. However, this was not seen as important for the use of the robot and for this reason no digital position sensor was selected for the motors. However, the drive motors as well as their power supply and control electronics are oversized so that the component selections also work with a heavier robotic frame and it is possible to run all the motors simultaneously. The limit switches take care of the hand movement limits so that the hand does not damage itself by hitting the robot body or other parts of the hand. The user must make sure that the hand does not damage itself due to the environment.

2.2.2. Audiovisual

The function of audio playback in the robot is to enable two-way communication between the remote user and people in the vicinity of the robot. Thus, the robot needs both speakers and a microphone. Communication takes place using the main processor via the Internet. To amplify the audio signal, an audio amplifier circuit was built for the speakers.
Two Visaton DX 10-4 speaker elements were selected as speakers. The impedance of the speakers is 4 Ω and the rated power is 50 W. According to the sound requirements of the robot, the sound pressure must be at least 70 dB measured from

a distance of one meter. The required volume control option is currently available through the main processor operating system or network interface [5].
The camera chosen was Ricoh Theta V, due to high image quality and programmability through interfaces enable smooth streaming for the needs of the project. The camera has two wide-angle lenses on each side of the device. Together, they cover a 360-degree field of view. The main features of the camera are 3840x1080 resolution video, which can be streamed to a computer via a USB cable.
The built-in microphone of the camera used in the robot has been found suitable for this use in preliminary tests, so a separate microphone is not required. The required microphone frequency range was defined in the specification as 85 - 10,000 Hz, this is likely to be the case, but it has not been verified by testing.
A 360-video viewing feature and virtual controllers for driving the robot and controlling the robot hand were implemented in the web interface. WebRTC technology is used for data transfer, which can achieve low latency [6]. The connection is between the two sides (P2P). Network interface and the signal server required connecting the two sides was placed in the Microsoft Azure cloud. The robot's main processor platform is Intel's NUC minicomputer. The computer transmits control commands via the serial bus to the microcontroller controlling the motors, as well as captures the image stream from the camera and forwards it. A screenshot of the user interface is shown in Fig. 2.

Fig. 2. Robot web interface. The image of the 360-degree camera can be rotated with the mouse. Below the picture is a joystick that controls the robot's drive motor and swivel wheels. Each axis of the robot arm is controlled by a pair of buttons. [5]

2.2.3. Mechanics

A square aluminum profile was chosen as the robot body material. This was chosen in part because structure is easy to change if problems occur, secondly, the material is extremely easy to machine and join together. When the development of the robot continues, the body material will probably be changed to a less modular solution.
The base of the robot body is assembled in Fig. 3. Rest of the parts are then stacked on top of the body of the frame. The base of the robot hand comes to a height of approx. 90 cm from the ground, so it can reach for the items on the table. Camera is attached on a pole as a highest point of the robot. This allows the camera to see anywhere around the robot. The base of the robot is about 50 cm wide, so the robot can pass through the doors.
The robot has swiveling front wheels that are steered by a stepper motor a bit like a normal car. This is a simple approach to implement in a prototype project. A differential was attached to the rear axle to improve the maneuverability of the robot. The steering angles of the front wheels were dimensioned in the prototype phase by utilizing the Ackermann condition.[5].

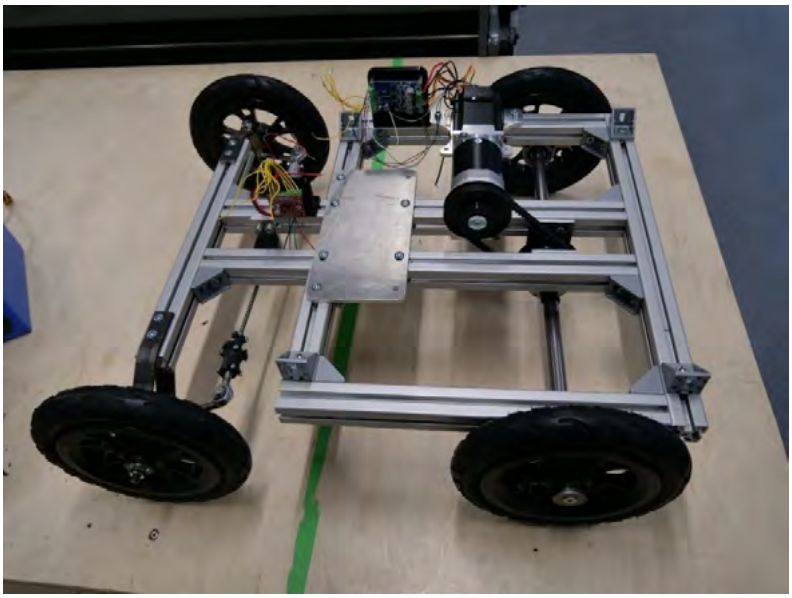

Fig. 3. Base of the robot

2.3. Testing

The testing of the prototype was scheduled for March, however SARS-CoV-2 pandemic caused delays in finalizing the design and testing of the student version of the telepresence device. Experience from other telepresence devices [7] [8] and the limited testing made it possible to inspect what the priorities should be when creating next version of the device.
The remote connection and use of a telepresence device was tested on May 26th. Students were allowed to test and use a telepresence device located at M5 Industries, San Francisco. This test session gave a sense of using the device and helped them design the device forward.

3. RESULTS AND DISCUSSION

3.1. Learning experiences from the telepresence devices

One of the main issues that came up is the great degree of linkages between various aspects within this project. Building a telepresence robot is a very technological enterprise, but in the end, enabling people to act over a distance is paramount.
On the technical side, a minimum level of functionality emerged. For example, it is imperative that latency should be as low as possible. There are numerous ways of optimizing it, by first identifying exactly where it occurs. It may not be from anything to do with the robot's processors. The bottleneck could quite easily be the internet because of bandwidth limitations or distance, or it could be the quantity of data that is being retrieved.
Coordinating behavior in a remote-controlled device is likely to be most compromised if camera resolution and latency are not adequate. Otherwise while many possible features are optional to have on a telepresence robot, in general it is best wherever possible as a default to at least replicate what a human would experience if they were there instead of the robot.
Along with transmitting high definition images, zooming in or any other way of getting a detailed image is adequate – as long as it does not cause latency. It may be necessary to give high definition only to portions of a given image, like elements that are changing, or elements like a human face, which can be done with existing algorithms.
A discussion arose about the human-like features of the robot. What qualities must it have in order for conversation to work through it and for teaching to become possible? Since the telepresence robot's primary function is to be a surrogate for interaction with humans, it should have something that is equivalent to a head or face, which would be able to acquire a face to face position. Ideally, it would also be able to move its head, with its camera and sensors, from a height of 1 meter (approximately desk top level) to a height of 2 meters in order to be at head height and line up face to face with an adult that is either seated or standing. Head movement should replicate that of a human as much as is practical, to make interaction with it similar to that between people. While it would be possible to have a simple pan and tilt movement of the surrogate head, like what a common camera gimbal has, having the head on a neck that can lean the head forward and up or down, side to side like a human's does could lend a more organic quality to the robot and broadcast the intent of the operator. Coordination of a head and neck turn with movement of the base for example can be choreographed through animation algorithms to happen sequentially; for example first the head and neck turns and then the base turns, which will provide a subtly more organic or life like presentation to people it is interacting with.
One is best served by not replicating literally everything a human does (like for example having an animated mechanical rubber human face), as much as capture the experience or intent. Not only is it complex and difficult to create a human face with the normal compliment of expressions but doing this commonly puts a robot in the well-known "uncanny valley" which is counterproductive. It would be preferable to

be done metaphorically, or with very similar functions that are more practical. For example, a screen with an image of a face on it is likely to be better than a rubber mechanical one; in general, if the robot is able to accomplish a task, it's not so important how. Secondly, there is no reason that improvements or additions to human functions cannot be had in such devices. Multispectral cameras can show a user more than what a human eye sees and amplified, or enhanced hearing could be provided. Things can be automatically recorded by the robot to be played back, or even physical feats like employing computer precision as a sort of augmentation to a movement- like drawing a perfectly straight line with a marker on paper that most people either can't do or do as well with hands alone is just one example. These things can be either just bonus features, or they could be seen to even the scales, considering that the robot will not be able to do normal things like sense touch and smell that are not practical to try to replicate, and that there are going to be intangible things an actual in person meeting will have that a telepresence robot would not be able to provide.

Having the base able to rotate in place and move in all directions smoothly will also enable it to fit and move in areas the same way a human would in close quarters. While the speed of the robot will be limited to normal human walking speed and would not be heavy or powerful enough to seriously injure a bystander, obviously the robot or things it runs into could be damaged if it hits them. It might be advisable to install a pleasant sound generator that comes on, so people present know when it is moving even if they are not watching it.

The above-mentioned large number of different connections forms the body of this project. There is a constant need of iterative reasoning and testing after every solution made. This came apparent both in the short and long term, that is within one semester and within an annual continuous and evolving project (this last in the form of challenges for the coming periods). Although we had an idea of this in advance, we still found that it would be good for students to have a stronger role as a tester, in addition to the role of builder. Technological development offers a lot of interesting things to do for creative minds, but the actual results will be seen only through learning. The project itself is one learning environment, but the real benefit of the device comes through other courses, teaching in laboratories.

These aspects highlight the need for a more structured process of testing during the next seasons: user experiences need to be collected, data analyzed, and utilized in subsequent design rounds. This outcome is clear, and expected, but it forms an interesting tension with the nature of this project. Because of the large number of different connections and iterative processes, it is not possible to proceed through a pre-planned linear project; or we would omit a large number of development steps because of the clarity of the process, and the sense of control. This sparked a debate: whether we teach rapid product development or manageable clear projects.

It is likely that telepresence teaching in higher education organizations will increase in the future. Our aim was not to present a blueprint of ultra-modern telepresence device, but to illustrate that this technology can be produced as student projects. The telepresence technology enables visits by specialists in laboratories with less required time, costs and emissions compared to travel. It also opens the door to

actual improvements on the way we interact as a result of the ease of the act; people are under less stress if they are not jet lagged from travel or away from their families and the comforts of home, and we must keep in mind that even if we have effective medicines to deals with the current pandemic, the common cold flu and other illnesses – which have a comparably negative effect on people will be better avoided by having unnecessary contact outside one's local circle. However, this is just the beginning of a new era and, in addition to technical expertise, different pedagogies and ethical rules for action are needed. An important consideration is also the potential misuse of the tool; are there unethical ways to use telepresence robots in an educational setting and how could they be prevented? When telepresence devices become more common, general rules for their use are also needed.
Future practical experiences with our telepresence robot in the prototype laboratory will help us to develop both technology and practice further. Perhaps in the coming years, a whole new culture will be created for teaching through telepresence robots. Between the potential advantages we have listed and the inevitable technological improvements in the human/machine interface that will come from the student crowd sourcing of changes we are encouraging students to make the designs, we may anticipate that this type of robot assisted remote teaching could become accepted as at least equivalent, if not superior at times to the standard method.

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EXPLICATION AS A DRIVER IN INNOVATION AND ENTREPRENEURSHIP

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Conference Key Areas: *Engineering curriculum design, challenge based education*
Keywords: *Design process, explication, effectuation, engineering curriculum design, innovation education.*

ABSTRACT

This paper presents a cross-course design and the underlying model and explains how we use explication of knowledge (Nonaka 1996) as a core element in both courses. The purpose of the courses is to foster entrepreneurship among engineering students at the Technical University of Denmark.

For five years, the authors have run the two courses 'Green Entrepreneurship' and 'Prototype Development' in close collaboration and prepared the students for the internal university competition Green Challenge. Industry representatives, politicians, researchers and students judge the challenge. From 2015 to 2019, our students had eleven out of twenty-one possible top three rankings in the competition.

Whereas the two courses present the students to various theoretical concepts, they both facilitate the students to iterate in multiple loops, investigating the context, gaining knowledge, (re-) defining the problem, explicating proposals to an audience and retrieving feedback.

We argue that one single factor why the students do well in the Green Challenge is the recurring explication where the students express their emerging understanding (Lawson 2005) of the problem in recurring pitch situations. For each new explication in the course, the students become more accurate in their communication, more conscious about the context, and reach a new level of understanding of the problem, as a solution emerges.

The data behind this paper is student material presented throughout the two courses, the student's final reports and the competition results.

The paper is a conceptual paper that proposes a design for an entrepreneurial course with the recurring explications as the driver.

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1 INTRODUCTION

1.1 Preface: The situation of explication

In a few days I will be responsible for an event, scheduled for a while and entitled *"Workshop with the hospital"*. It is related to a new innovation project with the aim of *"Empowering the Innovation Ecology at the Hospital".* At the event, the project group will pitch the core of the project to the management of a potential partner organization, hopefully to obtain their support. When the project group last met a month ago, a number of to-do's and important questions were articulated and delegated. Since, reflection has taken place but everyday-business has occupied most of the calendar. Now the advancing deadline triggers action. Energy rises. Mails are sent. Telephone and Skype calls take place. Agenda, project proposals and slides are drafted, circulated and refined. Difficult decisions are suddenly made swiftly. At the upcoming event a project proposal finished in the last minute of the 11th hour will be explicated, expressing our most present understanding of what we are up to. The minute before the event we will probably have a common belief of what problem the project is about to solve and how to solve it. But likewise probably, the minute after the presentation, when we have sensed the mood of the room and got the response from the audience, our priorities are no longer that certain. Our basic assumptions might have side stepped a little. New aspects are brought into consideration and aspects we previously considered to be inferior are now in focus. The actual *matter of concern* has been subject for a *translation* [1] and *pivoting* [2] has taken place. Consequently, new domains of knowledge must be investigated. New experiments must be conducted. A number of to-do's and important questions are articulated and delegated. New events will be set…

Most project-workers and entrepreneurs are familiar with these endless loops of *situations of explication* with the derived translations and incremental steps forward. With the current paper we present and discuss a course design building on the hypothesis that these situations are not only a frustrating necessary evil, neither a moment of make or break, as claimed in popular TV shows like the Dragon's Den, but rather a chain of powerful situations where learning are gained and the innovation gradually *comes into being*.

1.2 The courses and the Green Challenge competition

In the present paper we take a look at the five ECTS course *62024 Prototype Development* (PD) [11] offered at DTU-Diploma, Copenhagen Denmark. PD is offered in the end of the academic year at second semester of the first year at the studyprogram Process and Innovation. To the students, PD is experienced as an extension of the five ECTS course *62014 Green Entrepreneurship* (GE) [12], offered earlier in the second semester. The students' work with the same project throughout both courses with the end goal of participating in the DTU Green Challenge (GC). GC is an open contest where more than 100 student-projects with elements of sustainability are evaluated and rated against four parameters by boards with

participation of industry experts, politicians, students and scholars. The top three projects in four academic categories are rewarded.

The two courses have been carried out in their present form since 2015. In the period our students have won eleven out of twenty-one possible top three rankings in the GC. In 2019, 30 projects participated in our category and we had seven out of our nine groups in top ten.

The courses embrace the significance of the situation of explication. In particular in the PD course a series of explications named *pitches* is the backbone of the course design.

With this paper we follow the chain of explications during the PD course 2019 exemplified by one selected group, hereafter referred to as Foamy by the name of their final product. The group ended up ranking nine in the competition, and as such average when it comes to the competition result. Wether the group is methodological representative will be discussed in the concluding chapter.

2 THEOERETICAL OUTSET

The theoretical justification for the hypothesis rest on organizational theory [5], Actor Network Theory (ANT) [1] and design theory [3,6,7,8,9]

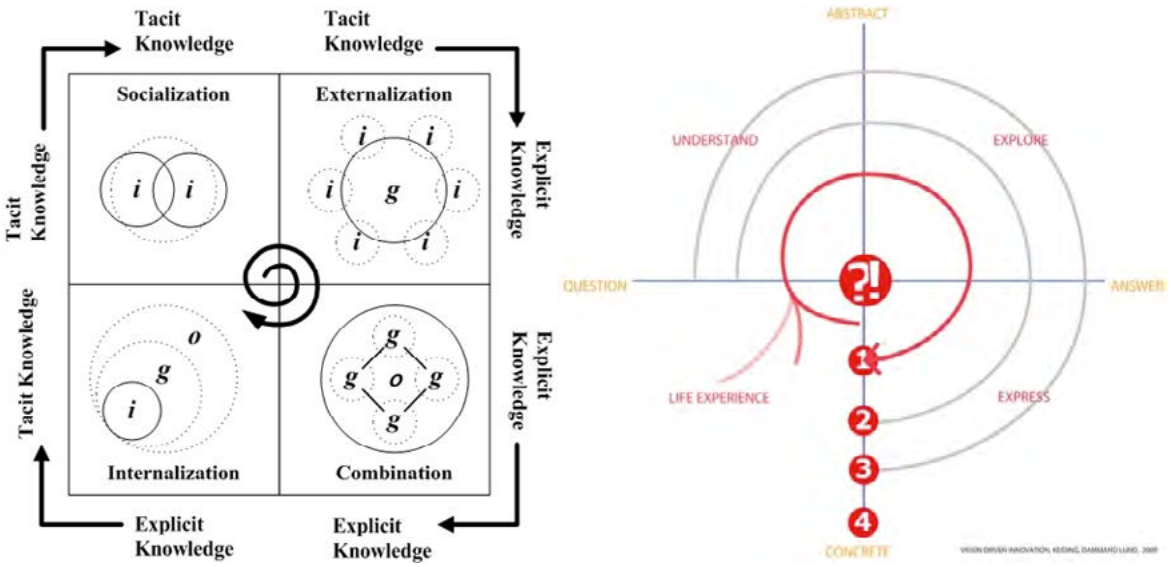
The SECI model (figure 1, left) illustrates the process of organizational knowledge creation where tacit and explicit knowledge is exchanged in a social dynamic. The term *explication* describes the action where tacit knowledge is translated into explicit knowledge and materialized verbally, as text, as prototypes or otherwise.

ANT explains how knowledge emerges while a *matter of concern* is subject to a chain of translations performed by multiple actors, where, in the context of innovation, the outcome is gradually stabilized. The term matter of concern (in contrast to *matter of fact*) states that knowledge is contestable and context dependent. In an innovation context a *matter of concern* describes an opportunity, a case, a problem or a problematic situation [8] serving as the outset for the innovation process. The concept of *chains of translation* is consistent with the concept of the design discourse [9], describing innovation as a process where key interpreters propose a vision to mobilize a network of actors with different perspectives to partake in interpretations that gradually shape and qualify the vision while it is materialized. A hermeneutic practice [6] takes place while problem and solution emerge together [7] The process alters between the core activities of the hermeneutic design process: analysis, synthesis and evaluation, as show in *the brick model*, by Lawson [7].

The VDI model[1] (Fig. 1 right) integrate the perspectives above. The *matter of concern* is the pivot of the process, shown as a unity of a question mark ('?' represent the problem) and an exclamation mark ('!' represent the proposed vision or

[1] VDI is an agronym for Vision Driven Innovation [3, 10]

solution). Each loop converges [10] into a situation of explication. The chain of situations numbered 1, 2, 3, 4, is shown down the vertical axis. Like Lawson's model, VDI is a hermeneutic design process model, but the phases are named by the narrative *understand, explore, express*, where *express* equals *explication.* The fourth phase; *life experience* (fig. 1 (right): lower left quadrant) represent the response from the world whenever something is spoken out loudly. *It's an ecco*, as we explain it to the students.The progress and ultimately the result of the process depend on the extent to which the key interpreter, that is the student, listens, learns and allows the response to shape the matter of concern at hand, and guide the process.



Figur 1(left): The SECI model [5]. (right): The VDI design process model [3]

2.1 Explication in a course context

Explications take place countless times during a process as the one described in this paper. Some explications are planned and inherent to the course design. This covers pitches and submissions, formel supervision, the exam and the final pitches at GC. Others are performed by the group as various kinds of interaction with stakeholders like expert interviews, user observations, workshops and tests of prototypes, or situated when e. g. group members present new insights to each other, or small talk at a family dinner. Ultimately, all situations can be regarded explications where *a designer,* e.g. a team member, *express* the intention and how to achive it and listen actively to the response, Any explication will articulate a proposal that is also a question, that is; *how do this relate to* your *experience of life?*

3 METHODOLOGY AND EMPIRICAL MATERIAL

This paper focuses on the Prototype Development (PD) course 2019 and the process of one team. Empirical data includes course material, scores and feedback from three PD pitches and the final exam, scores and transcripted video from the

final GC pitch, pitch manuscripts and other material handed in during the PD course, and teachers notes from pitches and supervision. See overview in table 1.

The VDI model and the narrative *understand, explore, express* is initially introduced to the students at the PD course.

The primary learning objective for the GE course *is to document a business opportunity in a business plan* [12]. As said, the students continue to work on the same project in the PD course, but to meet the learning objective to *develop a comprehensive prototype [...] as an integral part of an overall project communication* [11]. We put it slightly more straight forward to the students: They should make the business opportunity come into beeing!

3.1 The Prototype Development Course design

The PD course is a five ECTS course offered in a three week period in June. The subject of the course is *the process of prototyping*. It is a challenge based course with 40 students working in nine groups, structured in three *sprints* [13] converging into three *pitches*. The groups work independently and are self organized apart from an introductional day, the pitches and the exam. Supervision is offered throughout the course.

#	Planned by	Date	Situations of explication	Documentation
1	GE course		Half way pitch	
2	The Group		Interviews with healthcare professionals	
3	GE/ GC		GC abstract	Submission
4	GE course		Oral Exam	
5	PD course	0706	Pitch 1	Submission, notes, score
6	The Group		Workshop in the kindergarten	In reflection rapport
7	PD course	1406	Pitch 2	Submission, notes, score
8	The Group		Test in a kindergarten	In reflection rapport
9	PD course	1706	Pitch 3	Submission, notes, score
10	The Group		Presentations to healthcare professionals	In reflection rapport
11	PD course	2206	Reflection rapport	Submission
12	PD course	2306	Exam	Teachers notes
13	GC	2406	GC Pitch	Transcripted video, score

Table 1: Planned situations of explication on a timeline throughout the course and how they are documented. Some are part of the course design, others are initiated by the team. The table will be referred to by the numbers in the left most column.(tab.1 #n). Quotes are translated from Danish by the authors.

The pitches at the course are with some exceptions following the pitch format used in GC. A GC pitch has a duration of two minutes, then it will be stopped. It is followed by five minutes for clarifying questions, whereafter the panel evaluates the pitch compared to four GC parameters[2] and rates the pitch on each parameter on a scale

[2] Green Challange parameters [4]: On a scale from 1-10…

from one to ten. The group will pitch for three panels and a total score is calculated. Likewise the PD pitch has a duration of two minutes. A timekeeper will let the group know when time is up. The pitch is followed by five minutes of questions and feedback from supervisors and five minutes feedback from the class. Finally there will be a voting session and each team and the supervisors rates the pitch following the GC format in a Google form where also written feedback is optional. An average rating is calculated instantly and presented to the group.

To the students we stated that *prototyping is driven by feedback. […] Feedback is about learning, not about right and wrong or whether an idea is good or bad. […] When you receive feedback; • DO NOT RESPOND - you have no time for that, at all. The pitch is about getting the most out of your audience.* (From course document: This is how a pitch goes).

3.2 The Foamy process

The process of Group 7 exemplifies the concept of explication and the narrative of the VDI model. It is the story about the coming into being of *Foamies, some silly little animals living in the sink* (tab 1 #5)

Pitch 1: During the GE course Group 7 *focused on the social gain of more frequently handwash, especially with kids since they are more receptive to behavioral changes* (tab 1 #11). We step into the story at the first PD pitch. Based on dialogue with experts and employers at a kindergarten the group propose that:

…the low rate of people washing hands causes an increased rate of infections transmitted between people, especially between the staff and children in nursery schools. The solution is technological: *Sensors [and] a display with a loading bar gives feedback. […] The child can follow the progress, [and it] will make the children remember to wash hands.* (tab 1 #5)

The pitch audience acknowledged the matter of hand hygiene.The group claimed that *handwashing is fun* (supervisors notes) but this part of the proposal is met with concern: Is it really fun for kids to watch a loading bar while washing hands?

The collective voting resulted in a score of 9.0 out of 40, a thought provoking feedback: The audience simply did not approve the proposal. It can be painful when you *have build ownership* (tab 1 #11), but the group noted pitch 1 as a turning point since it raised an important question: *What do kids think is fun?*

The workshop: The group decided to go back to the kindergarten for further exploration (tab 1 #6). The question was translated into another guiding question: *How to turn time of splashing into time of washing?* (tab 1 #5) To involve the kids the

- Is the project well-structured and clearly communicated?
- To what extend is the positive impact on the UN Sustainable Development goals made probable?
- To what extent is the project technically applicable and likely to be realized?
- To what extent is it visionary and/or innovative?

group featured an outdoor workshop with water filled boxes and a lot of plastic toys. The kids were invited to *splash and wash*.

Figur 2 (from left): a:The workshop. b: The duck. c: Artifacts from the workshop. d: Early prototype made from clay and covered with silicone.

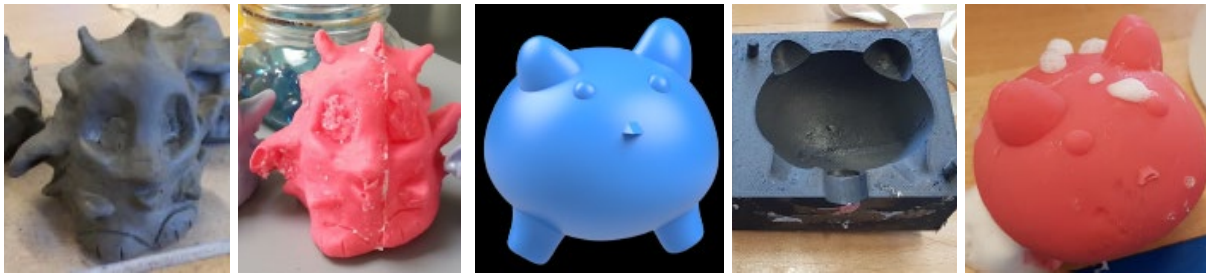
The workshop was a relief for the group as they *got an incredible lot of data back home from the visit at the kindergarten* (tab 1 #11). The kids responded with an obvious joy (fig 2a). One artifact; the duck, caught attention (fig 2b*): The kids loved washing it together. But would they also do it alone in the restroom?* (tab #11)

According to the group, the Foamy soap dispenser was born as a proposal at the following brainstorm and modelling session (tab #11) where the group, mimicking children's modeling, created little funny figures (fig 2d).

Pitch 2: The group showed little clay-figures (fig 2d, 3a) and proposed that:

…we want to make the restroom a playground! Our solution, made in collaboration with the children, is a figure-shaped soap dispenser that you simply cannot help but touch. [It is] soft, elastic, smooth and attractive. The dispenser should give the children foam soap on their hands as they squeeze it! (tab 1 #7)

It caused the score 26.88, a remarkable jump and the pitch audience were instantly mobilized to debate the matter of silicone molding and the technology of the soap dispenser. In the supervisors' notes it is quoted that *bathrooms are boring*, and the notepad is filled with drafts for dispenser valves.



Figur 3 (from left) a,b: Early prototypes. c: Digital model. d: 3D printed mould. e: Prototype with foam.

Here followed a period of technological development where 3D printers showed great *actans*, using a term from ANT compliant with Storni's *Notion of Things as a social construct* [15].

The first attempts to make a silicone mould from the clay form wasn't promising (fig 3a, b) but a simple 3D model (fig 3c) and a 3D printed form (fig 3d) proved doable. The group managed to produce a number of Fomies for testing (fig 3e).

Test: A simple test design was carried out: Soap-filled Foamies with tiny dispenser-holes was deployed in the sink in a new kindergarten. A local pedagogue agreed to observe the kids and take notes, an agreement that prevented the students from disturbing the kids and the test.

The kids used the Fomies as intended and caught attention at the kindergarten. Some parents even asked where to buy them. New questions arised: Will the interest persist? What about the soap consumption and how to refill?

Pitch 3: The Foamy narrative begin to stabilize and the focus is now on the staging of the final pitch. At this point, the group proposes the matter with authenticity:

Children discover the world through their hands! When they get soap on their fingers, they wash it off! This led to the creation of Foamy! (tab 1 #9)

Everybody loved the Fomies and the class score increased even further to 28.11.

The last period of the course is intense. The students are busy producing prototypes, trying to answer soap dispenser related questions, rehearsing the pitch, preparing the Green Challenge scenography and designing the poster.

The matter is gradually further stabilized: Notes from supervision in the period: *The sink is a playground!*

The Oral Exam acts as a final rehearsal, the group passed and got feedback once again. After a few more rehearsals and optimizations of the pitchmanuscript and the choreography, they are ready for the final explications at Green Challenge.

Green Challenge is a special day to most students that participate. Many weeks of work converge. The groups will propose to Industry professionals, entrepreneurs, business angels, politicians and fellow students, and for many this event is an important step in a startup process or a research career, as many will gain confidence and also be introduced to important new contacts. The groups will have to explicate to strangers with different backgrounds. The Foamy Group has a nice scenography with sink, water, poster and a lot of Formies for the audience. They stick to the narrative but accentuate the economical argument:

Two million days of sick leave a year is registered at the Danish labour market - not because employees themselves are sick but because their children are. 30% of children's sick days can be attributed to hand hygiene. Foamy can save 600,000 sick days a year. We have been out in public kindergartens, playing with water with the children. They had fun. Children experience the world with their hands. When children get soap on their hands, they wash it off automatically. We put that information into a concept, brought it to Herlevgaard kindergarten and tested and that test gave us Foamy. Fomies are some crazy animals that live in the sink and the kids can't keep their hands off them. When the children hug them, soap comes on their hands. And then there's just one thing to do and it's to wash your hands. Foamy changes the behavior of the kids. We have presented to a hygienic nurse and a

doctor. They confirm that the way to better hand hygiene for children is to change behavior (tab #13)

Group 7 achieved a Green Challenge score of 26.33 which ranked Foamy as no. 9 out of 30 groups. One board member wrote: *Making better health a game. If implemented a revolution!* (tab 1 #13).

Further on

The Group was encouraged by the experience at the Green Challenge. Since GC, they have taken the project to another course and also formed a small enterprise, trying to get croudfunding. They continue to explicate their rising understanding of the matter of hygiene and children. If they respond properly to the present societal response and translate the Fomies accordingly, there might be another story to tell.

4 CONCLUDING SUMMARY

This paper proposes a design for an entrepreneurial course with the recurring explications as the driver. We argue that one single factor why the students do well in the Green Challenge is the recurring explications.

The story about Foamy exemplifies how our students, for each new explication, get their narrative more accurate, become more conscious about their audience and the societal context, and reach a new level of understanding, as the solution, in this case the Foamies, comes into being and matures.

The example stresses the interconnectedness between the depth and width of the understanding of the matter; children's hygiene in the kindergarten and its societal consequences on one hand, and the applicability and possible adaption of the solutions to a market on the other hand. As Lawson put it; problem and solution emerge together [7].

We claim that the story about Foamy is not unique. Since 2015 we have seen many of the kind, judging by the track record of our students in the Green Challenge. Also, explication is not restricted to a learning context. You might argue that using the Green Challenge as motivation for the students makes the whole thing unrealistic since it is ‘only’’ an university competition. We will argue the opposite. What motivates students most is to experience their proposal coming into being. In the present case, the students are not only rewarded with a grade (pass/failed, not much glamour about that), but by the response and engagement from numerous actors along the way, ranging from the kids to the professional members of the GC panel, proving they are making sense. In several cases, whereas Foamy is one, the students take the leap and form an enterprise. Whereafter they can expect an infinite chain of situations of explications while they aim to mobilize partners and customers, hopefully gaining the understanding of society, market and human behaviour, necessary to succeed. And so can the rest of us, pushing our projects forward within the walls of an organization, as exemplified in the preface.

4.1 Explication or feedback?

We claim that one single factor why the students do so well in the Green Challenge is the recurring explications. With reference to the VDI model one can ask what happens to the *understand, explore* part of the narrative? Also, isn't the feedback equal important to the explication? The learning circle is of course inseparable, but as an engineer, an innovator or an entrepreneur, you attempt to make an impact to the world. The situation of explication is the scene of your attempt, a situation where knowledge and opportunities converge and come into existence. Without the explication there might be, best case, a Nobel prize candidate manuscript hidden in the desk drawer, read by no one. The explication generates response to learn from. Feedback is one kind of response, often associated with the learning relation between teachers and students, but response is a lot more. Drift wet children, deeply engaged in washing a yellow plastic-duck in the kindergarten is a powerful response, confirming that the students in that particular moment are on the right track and make sense.

To summarize, the moment of explication can somehow be controlled. You can decide time and place and you can choose what to say and what to show. The feedback can be documented, processed and analysed, but the feedback itself, how exactly the kids make fun, is out of control but an important source to learn from. In this sense the Fomies is a gift from the kids in the kindergarten to Group 7.

4.2 Resistance and the learning curve

Internalization of the narrative of explication is not easy for students. There is a learning curve. As quoted above, the idea of personal ownership to a concept of great value is deeply embedded in society and painful to give up. But in a learning context we claim that to give up ownership and let go of ideas might be the far most important learning. Explication offers a perception that is in opposition to the mainstream judgmental 'make or break' narrative of the entrepreneurial pitch. Instead we claim that whatever you propose, you should consider it a probe, pay attention to the response and be ready to leave your believes behind. One other group attending the courses worked on a project for 13 weeks in the GE course, proposed it on PD pitch one, got feedback similar to what the Foamy group got, decided to give up the project, started all over with two weeks left - and won the Green Challenge.

With the two courses we intentionally give the students a lot of options to explicate their matter to an audience as diverse as possible. This, accompanied by the experience of bringing something into being facilitates the internalization of the narrative of explication.

4.3 Concluding remarks

The foamy example is only one out of nine from the year of 2019, that again is one year out of five where the described coursedesign has been carried out. The VDI model and the idea of recurring explication has likewise served as model at other courses and projects as well as innovation processes in professional arenas, e. g.

the international society of audiology [3]. The Foamy case is simple, at least from a technological perspective. Some might even call et simplistic. But the curriculum at the study program Process & Innovation aim to enpower the students to manage the socio-technological complexity of a multidiciplinary innovation process. From that perspective there is plenty of complexity and learning in the intention of making handwash fun for kids. The students will soon get involved with more advanced technology, byt then they are prepared to balance technology with human, cultural and economical factors troughout the process. Future research must explore the concept of explication in these more complex processes.

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MODE OF DELIVERY: ONLINE, TARGET AUDIENCE: PROFESSIONALS; DEVELOPING AN ONLINE PORTFOLIO FOR PROFESSIONAL LEARNERS REQUIRES NEW SKILLS IN AN ACADEMIC INSTITUTION

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Keywords: *online learning, professional learning, course design, institutional development*

ABSTRACT

The courses in an online learning portfolio for the professional market have different characteristics compared to those in residential bachelor and master programmes. This includes the mode of delivery: online versus face-to-face, as well as the audience: professionals versus degree students. Developing such a portfolio entails a different approach for defining learning needs and learning outcomes, for course design and development, scheduling, marketing, credentialing, etc. It means that the institution needs to develop new skill sets in various areas: translating the market needs to learning outcomes, expertise on online pedagogy, platforms and tools, technical support and support for online learners. On the level of the organisation, management, policy and human resources need to recognize that offering this type of education forms part of its activities and ownership needs to be in place at different levels. This paper describes how the TU Delft learned what skills and processes are needed to develop and offer the online portfolio for professional learners, what this means for the organisation, and how it was implemented. It includes the criteria to select courses to include in the portfolio, the differences in learning needs between professional learners and degree students, the issues to take into account when translating the learning needs of professional learners to an online portfolio, the specifics for course development, and the processes developed to implement these in an academic institution.

1. INTRODUCTION

The TU Delft offered its first MOOCs in 2013, started its Open and Online Education programme in 2014, offered its first online Professional Education courses by 2015, its first Professional Certificate Programme in 2016, the first Delft Micromaster in 2017, and has developed by 2020 into an organisation with a portfolio of over 100 MOOCs and over 50 paid courses, approaching 3 million enrolments overall. The objectives and organisation have evolved with these developments [1], [2]. The new activities made it necessary to acquire new expertise and develop knowledge, skills and organisation to deliver these open and online offerings successfully. With the increase of the number of courses to be developed and offered, we saw the need to create efficient work processes ranging from those for Portfolio Development and Course Development to Video Production, Marketing, and Administration. In this paper we describe what we achieved, and what we have learned in the process.

2. SPECIFIC REQUIREMENTS FOR ONLINE COURSES FOR PROFESSIONALS

2.1 Professionals have different learning needs compared to degree-students

Professionals have different learning needs compared to the Delft campus students: they look for applicable skills, have broader range of backgrounds, generally a higher age and less time available for education. The added value of a course needs to be apparent in the course description: as learners want to advance their career, they need to see what they can do more, or better, upon finishing the course. This requires a thorough understanding of your learners needs and pain points. We have implemented several ways to meet the need of the professional learner better in our courses. One is to involve the targeted learner in the course development process, in the form of full co-creation, or in the form of feedback at various moments in the process. Another is to give professionals a role in the course, as “Voices from the field”, for example in the form of interviews, a practical case, or through participation in the discussion forum. Furthermore we analyse the pre- and post surveys the participants complete in a course: who are the learners, what were their main takeaways, what did they miss, to improve the course accordingly. As credentials are relevant, but these non-degree courses can mostly not be connected to credits in the ECTS, we issue other credentials: Continuing Education Units (CEUs). These are connected to the time a learner is expected to spend on the course. Implementing this in an academic environment involves a shift in mindset from the instructor, and collaboration with the business team.

2.2 Mode of delivery: online vs face-to-face

The lecturers at TU Delft are used to designing and providing education for bachelor and master students who are present on campus. The education is structured on the basis of scheduled lessons, practicals and exams. Campus students generally study full time, 40 hours per week. An academic year is divided into four quarters and each quarter ends with an examination period in which students complete the mostly mandatory courses and receive credits. Campus courses are therefore grade-oriented and form part of a curriculum.

In 2013, online education was completely new for the TU Delft lecturers and the support staff. As campus education was the frame of reference, the first online courses were derivatives of campus courses. These had comparable learning objectives and study load, and mainly consisted of video lectures and quizzes.

Our online courses reached a completely different target audience, namely lifelong learners and/or working professionals. With their different time zones, sometimes full-time jobs and busy private lives, they need education that is time- and place-independent, and flexible. Schedule and study load must be adapted to their busy agendas. The content needs to be highly relevant and immediately applicable. In table 1 the main differences between campus education for degree students and online education for professionals are summarized.

Campus Education for degree students	**Online education for professionals**
Structured by scheduled classes	Time and place independent
Grade-oriented	Knowledge & skills oriented
Curriculum focused	Stand alone with more diverse audience
Higher total and weekly study load	Lower total and weekly study load

Table 1. Main differences between campus and online education

3. DEVELOPMENT OF EXPERTISE AND PROCESSES

3.1 Portfolio development

The selection of courses to be included in the online portfolio is through a tender process: faculty members submit a proposal which is evaluated and granted by the Open and Online Education (O2E) program committee. The criteria for this tender have developed over the years. In the first years of the O2E program, the focus was to build up experience and expertise in online course creation and delivery, and the criteria focused on the educational quality of the course and the O2E programme committee granted and supported almost all courses proposed. As the O2E programme progressed, the number of online courses available worldwide grew to thousands, and it was more difficult to attract the envisaged number of participants. The development, production and offering of online courses requires a significant investment of time and resources, which can only be justified when a certain audience is reached. We recognised the courses were only successful if they have a certain uniqueness, provide additional value to the learning landscape, and are aligned with the TU Delft organization. We learned more about the characteristics of the courses that resonate with a professional audience, like meeting the learning needs of professionals. This way we developed a tender procedure with selection criteria that are regularly reviewed and adapted, to respond to the changing world. The resulting selection criteria are listed below.

1. The programme has unique features and learning outcomes: a successful programme adds value to the global online learning landscape; it does not duplicate what is already available; and a top-reputation helps to have learners find and select the programme.

2. The programme offers knowledge and skills, relating to proven labour market needs in a flexible, accessible and focused way: to attract a substantial audience, the programme is tailored to the learning needs of working professionals, in terms of content and mode of delivery.

3. The online programme ideally contributes to improving the quality and efficiency of campus teaching, and/or to research, branding, and forging new collaborations: the course materials, and course or programme results, will be used in campus education (in- and outside TU Delft), and/or to achieve other goals.

4. The programme and course production process is efficient and effective when the course team members have the expertise and are able to allocate time: a driven and motivated course team will ensure timely delivery; the programme should start within one year after approval.

5. The faculty is the owner of the programme, and commits to at least three runs, unless agreed otherwise: the programme is in line with and preferably strengthens the faculty strategy on lifelong learning, and builds upon the faculty's strengths; the faculty management commits to support development and running of the programme for at least three years.

6. Collaboration with industry results in courses/programmes that are better aligned with the needs of professionals as well as contributing real-life case studies: one or more corporate or public partners are identified to provide a 'voice from the field' and/or to 'co-create'.

7. The Extension School is building a portfolio that is aligned with the University's strengths and UN's Strategic Development Goals: the programme adds value to the Extension School's portfolio.

8. Programmes provide an extensive learning experience, give individual courses value and are easier to market: the proposed programme forms a coherent whole.

Developing and implementing these criteria has resulted in a better feel for which courses can be successful, and it has also led to the recognition of the necessity to align the objectives of the O2E programme with those of the faculties. It is not only applicable for new courses, we also improved and/or bundled existing courses to better meet these criteria to result in more impactful courses for learners. This process of embedding is ongoing and continuously adapted based on findings and experiences.

3.2 Course development

To ensure high quality online courses we created and implemented the Online Learning Experience (OLE) pedagogical model [3]. The OLE model consists of 8 principles which define TU Delft's online courses.These principles are: supportive, interactive, active, authentic, innovative, flexible, diverse and inclusive. The principles have been translated into different supporting documents and are applied in the different phases of the course development process.

3.2.1 Course development process

In order to support course teams well, a detailed course development process has been defined that consists of a number of phases.

Figure 1 Online course development process

Each phase consists of a number of steps that the course team must go through. In the Plan Phase, course teams are trained in online education (on boarding day), the course is designed and production and marketing prepared. In the plan phase, the value for the learner is made explicit with the marketing team, and we use the Carpe Diem approach of Gilly Salmon [4] to design the online course. In the Produce Phase, the course content is produced, such as assignments, texts, media and assessment. The course structure, based on the storyboard, is included in the online learning platform and a beta test is carried out. The Delivery Phase focuses on offering the course, and improvements are identified. In the Evaluation Phase the whole process is evaluated with the course team and the next run is prepared. Input for this evaluation is feedback of learners collected through questionnaires, combined with platform data and enrollment numbers. In this way we create a cycle of Quality Assurance and continuous improvement of courses.

3.2.2 Online learning Hub

Course teams are guided by a learning developer to apply the OLE principles in every step of the course development process. Over the years we have developed a variety of supporting materials and workshops to implement the OLE, which are used in the various process steps. These resources are accessible for everyone in an open hub (http://onlinelearninghub.tudelft.nl). For each phase in the process, the website describes the products to be delivered and which supporting resources can be used best. The resources consist of templates, guidelines, manuals, good

practices and workshops that course teams can take. For instance, in the production phase, where a course team might want to produce videos, the resources include a Script Writing workshop, a workshop Presenting in front of a Camera and a Video Editing workshop. In addition, there are various fact sheets with tips and tricks about video production.

3.2.3 On Boarding Day

To quickly familiarize new course teams with online education, we organize an On Boarding Day for all approved projects after each tender. On this day the new course teams get a chance to meet and become acquainted with each other. Moreover, they get to know each other's projects and learn how support for online education is arranged at the University. They also receive information about the innovation program “open and online education” of which they are now part and they start with defining the target audience of their course, their course design, and project planning.

3.2.4 Lessons learned in course design

Over the years, we have learned more and more about how best to set up an online course, so that a meaningful, engaging and feasible learning experience is created for the working professionals. Lessons learned include: optimal course length is about 4 to 6 weeks with a workload of 4 to 6 hours per week. It is crucial to create a highly engaging first week, to allow learners to evaluate whether the course is worth the time they allocate for it. This means that they should see interesting and engaging content from the first minutes on. An introduction and orientation to the platform are in a side menu. It is very important to vary in learning activities and formats to keep people engaged.

3.2.5 Cross over to campus education

When creating a MOOC or professional education course, lecturers increase their knowledge and skills in learning technologies, online learning activities, creating media, developing online assessment and interacting online with learners. Consequently, they apply these in their regular campus courses as well. The majority of the online courses developed within the extension school portfolio, have their effect on campus education. They are applied in various ways, which has resulted in increased flexibility of campus courses and and increased variety of digital materials. These enhancements are much appreciated by both lecturers and students. Furthermore, we use a similar course development process for redesigning campus courses toward blended formats as we use for online course development. Especially during the corona crisis, when all campus courses had to be delivered fully online, our expertise in online course development has proven to be very valuable.

3.3 Reaching the target audience

After fine tuning the course content and design to meet the needs of the professionals, we need to reach this professional target audience. This requires another approach compared to communicating to future campus students. As the course team members are experts, and have a network, in their field, we work with

them to define an approach on how to best reach the audience. The target audience and main take-aways are made explicit in the course announcement, in a language that is more practice-oriented and less academic. To help the instructors reach their network, we developed resources and materials of which the "Marketing Menu" in fig.2 is an example. Other examples are texts and visuals for use in social media, signatures in emails, and printed materials.

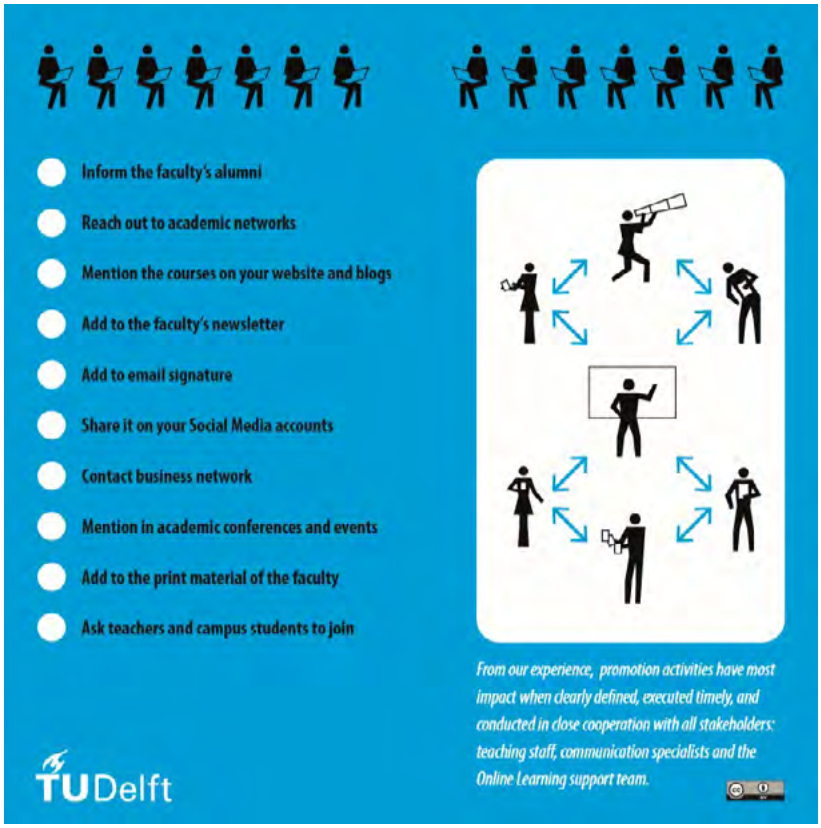

Figure 2 Marketing menu for online courses

4. CONCLUSION AND OUTLOOK

Setting up and maintaining a successful portfolio for life long learners and working professionals continues to be a major learning process at TU Delft. The differences with Bachelor and Master education forced us to develop new expertise, new work processes and a support organization for portfolio management, course development, marketing and quality assurance. These work processes need continuous adjustment to make them more efficient without losing the tailor-made approach that recognises that each course has its specific characteristics.

Our future challenges lie in finding the balance between the objectives of the different faculties for open and online education and meeting the market demand, to result in a coherent portfolio of courses that add value to the learning landscape.

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MODULARISATION IN ENGINEERING EDUCATION

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ABSTRACT

The present study is concerned with the modularization of courses in engineering education, in particular mathematics modules in/for physic education, at a Dutch university of technology. One of the project objectives is to develop and validate a framework to support teachers with their modular course design; another to provide supporting tools for students to navigate through a modularized system. This paper draws attention to the first stage of the project, which focuses on a state-of-the-art literature review regarding modularization. After a thorough literature review conducted in a systematic manner, with specific keywords, all relevant research papers were categorized under the following three dimensions: instructional activities and learning materials for modular courses; assessment procedure; and supporting systems needed within modular systems. According to the results from selected countries (e.g. UK, Ireland, Australia, Netherlands, and Germany), we have chosen to highlight those where modular system experiences were shared from the point of new instructional methods and learning materials created. Another group of articles were concerned with feedback mechanisms and assessment tools used in the modular courses. The last group concentrates on the ways how both students and instructors are supported in a modular system. This study reports on an overview of articles in terms of the three key criteria required to develop and validate a framework to support teachers at TU/e with their modular course design.

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1 INTRODUCTION

In the world of globalization, higher education is inevitably affected due to the increase of transnational flow of people, knowledge, and resources. The social arrangement within and around the universities take on a new significance as internationalization. Internationalization is actively encouraged by the Organization for Economic Co-operation and Development (OECD), European Union (EU), and United Nations Educational, Scientific and Cultural Organization (UNESCO).

One of the important impacts of internationalization is the emerging need for instructional systems in higher education to be made available to larger number of students in a life-long learning concept. Moreover, these new instructional systems also have to offer an individualized learning experience for students with different educational needs and backgrounds. Modularised systems come into prominence in order to provide the opportunity to perform the mentioned issues effectively. Modularisation can be defined as [1]:

> the process by which educational awards are broke up into component parts of a more or less standard size. These parts may then be assessed separately and independently, so that students can study individual modules in a variety of different sequences.

Modularisation of the curriculum is a shift from a time-based to a credit-based structure that caters for the needs of a more diverse student groups. It is also based on a fundamental principle to divide learning into measurable, quantifiable units of knowledge called modules. Students earn credits for modules that can lead to a qualification requiring a certain number of credit points [2].

Modular systems possess prominent features that can be seen to provide an attractive alternative to traditional-based ones. Flexibility in choice and mobility are the key elements of modularization, and they hold the reason to its current popularity. Due to flexibility and mobility, students can continue their education according to different circumstances or interests. Modular system schemes are actively student-centered, and students can shape their courses according to their needs, such as proceeding at their own pace, following individual learning paths and arranging personal learning times. Besides, courses in the system include a wide range of instructional activities that allow students to choose their learning modes. Additionally, assuming that not all the students have the same areas of interest and motivation goals, a larger variety of topics are typically introduced. One of the most notable advantage is that students can ‘walk through’ the module at their own pace, repeat or change the learning mode, which help students to identify their own weaknesses and strengths, and to achieve to complete the module with a fuller understanding [2,3].

The study reported in this paper is part of a large-scale curriculum reform project at a university of technology (in the south of the Netherlands), which aims to change its

curriculum from a rather 'traditional' engineering curriculum to a challenge based one [4]. Within this scope, it expected to take the advantage of modularisation as offering students opportunites for designing their own learning trajectories with respect to their individual needs, interests and aspirations via knowledge bites modules that can be taken 'just in time'. In this paper we aim to identify particular issues (from the literature) that would help course designers in engineering education to design modularized courses, so that students can develop their own learning trajectories. Our research question is the following:

According to the literature, what are the issues that a course designer/teacher has to consider for the design of his/her modular course/s?

After this introduction part, we provide an explanation of how the study was conducted. In the third section, we present the results from our study of the literature, under related subheadings. In the (fourth) conclusion section, we present the important issues for modularizing a course in engineering curriculum.

The study

From the methodological perspective, this paper is not a systematic "review study" [5], but rather a state-of-art review of the literature, which has been conducted in a systematic manner as described below.
As a first step, with the aim of getting an overall idea about modular systems and their difference from traditional ones, an initial search was conducted with the following keywords: modularisation; modularisation in higher education; modularisation in engineering education; modular systems. As the main aim of our project was modularisation of courses in engineering education, specifically mathematics modules in and for physics education, as a second step, we narrowed down the search with more specific keywords: modular courses; mathematics and physics in engineering; mathematics in physics; mathematics in physics courses; mathematics in physics modules; assessment in modules; assessment in modular systems; assessment in modular courses. A total of 122 papers were deemed to be suitable for analysis, and they were grouped in an excel sheet according to the keyword search.
In a third step, these searched articles were then filtered by screening the titles with the following criteria:

- the paper is related to modular systems in higher education or engineering education;
- the focus of the paper is related to mathematical knowledge in physics courses or modules;
- the paper provides information on assessment methods in modular systems or modular courses;
- the paper is published in a peer-reviewed scientific research paper, and
- it is written in the English language.

This resulted in 57 relevant papers. In order to answer our research question, we then analyzed and grouped these papers to help to identify criteria for developing a framework intended to be used for helping the designers/teachers to design and evaluate modular courses.

2 RESULT

As a result of our systematic literature review, we could categorize the 57 papers under three main headings:

- Instructional activities and learning materials
- Assessment procedure
- Supporting Systems

In terms of 'instructional activities and learning materials`, we collected all papers which mention the required issues for the new modularized learning environments from the point of instruction and learning materials, the specifically designed or constructed learning materials for the modular courses, and also the newly built instructional systems.

In the design process of a modular course, using efficient and comprehensive assessment tools are important, in particular for evaluating students' knowledge when they start a module (i.e. pre-knowledge), and when they exit a module (i.e. what they have learnt), but also in feedback loops to help students to assess where they are in their knowledge development and how to move forward. The 'assessment methods` category brings together the papers in which evaluation methods and techniques specific to modular courses are investigated.

The papers gathered under the `supporting systems` category assist us in exploring the ways of how all the stakeholders (students, instructors, assistants, etc.) of the modular system can be supported from different perspectives.

In the subsequent sections we report and explain our findings under the three headings.

2.1 Instructional Activities and Learning Materials

For the integration of an engineering curriculum into a modular form, from the point of instructional strategy the research literature suggests that classroom based and web-based modules have to complement each other to achieve higher rates of success in terms of student learning. While the classroom modules generally focus on the fundamental aspects of the topics, the web-based modules are said to assist with providing background knowledge and resources to help students learn with computer-assisted instruction and visual learning. With the advantage of computer assisted learning, students are provided with fast inquiry-based learning experiences and also allowed to proceed at their own pace and within their own schedule. Visual learning enables the use of graphics, images and visual supportive materials to engage students in active learning and help to make their learning experience richer [6].

In the modular systems, students have to create their own learning paths and make their own decisions through the modules. With implementing new education and instructional approaches (associated with e.g. problem based learning, competence based learning, or challenge based learning) to the modular systems, it is emphasized that within the courses conducted students acquire ownership of their learning experiences and become motivated self-directed learners [7-9]. It is also claimed that this offers students the chance to engage with real-life problems [7-9]. Another advantage is that students may become self-directed learners at an early stage of their undergraduate education [9].

A helpful point is expressed in the paper of Kezerashvili et. al. [10]: they claim that the integration of e-learning and e-teaching mechanisms support the active learning period of modular system. Based on their use and analysis of Blackboard and Website communication systems, they contend that greater student-instructor and student-student interaction were achieved [10].

2.2 Assessment Procedure

Modular courses typically offer many opportunities for students to develop their own learning paths, also linking to students' differing backgrounds. Therefore, it becomes essential to consider and plan effectively potential prerequisite routes through the curriculum, and to create and provide comprehensive, effective and efficient assessment tools/methods.
In the literature, it is highlighted that there is a necessity for shifting perspective from "assessment of learning" towards "assessment for learning [11]:

> A student focused approach is necessary if educators are to prepare a diverse student body, for diverse professional roles and if engineering education is to continue to progress, bold reforms of curricula and assessment need to be attempted and evaluated in a cycle of constant improvement

Another important point highlighted in the literature is connected to assessment procedures to be spread over the semester. It is recommended that these assessment 'steps' have to be conducted after certain parts of the module, to help students develop (a) self confidence in their own learning, and (b) conceptual understanding of the subject over modules and tests. In conventional courses, students are assisted at certain times via resubmission, feedback and coaching before the final assessment period. These steps are much more difficult to be processed in the constructed and pressured form of modular courses, and the assessment usually takes place at the end of each module. Hence, it is important to provide feedback loops throughout the module that 'feed forward' and potentially help students to move on. If the learner revisit the module at a later stage, there will be an opportunity for the feedback to have an effect on students` own learning path (or in the process of learn to learn strategy). As indicated by Cornford, many of the

problems of learning and assessment associated with modular courses can be overcome through planning for multiple and formative assessments [12]. Moreover, a mechanism (named 'feedback profiling tool') has been designed and shared by Hughes, Smith, and Creese. Its aim is to categorize the feedback and comments in the modular system and feed forward from one module to another to enable students act on feedback, so to develop student capacity to recontextualize disciplinary-specific skills throughout a programme [13].

In addition to the above mentioned issues, for assessing the progress of the modular approach, it is stated that building an evaluation team is an effective way for conducting the necessary principle tests: for instance conceptual pre- and post-tests, in-class and follow-up exams, the attitudinal pre- and post-surveys, focus group interviews, etc. [14].

2.3 Supporting Systems

Differences between traditional and modular systems create a necessity of supporting all the essential stakeholders, namely students and instructors, in many aspects.

One of the proposed suggestions is the employment of student assistants or graduate student instructors [14], with the aim of supporting the modular courses, running the discussions and laboratories and helping the students finding their paths through modules. Furthermore, due to increasing number of students enrolling, McGovern, Collier, and Magina proposed the intelligent learning assistants as an alternative solution to support students in their choice of modules via their learning and personal preferences, and academic capacities [15].

Another critical issue expressed in both papers by Gutwill-Wise [14] and Kieran and O`Neill [16], is the requirement for a professional development department (for teachers) or unit specific to modular system. If most of the students, student assistants and lecturers are used to traditional methods, it is advised to speed up their 'adaptation' to a modular system: for example, in terms of underpinning philosophical issues and main differences from traditional methods, of implementation ways/techniques of modular approaches, and also of the essential steps they can follow (typically conveyed through an established modularization education programme).

3 CONLUSIONS

The shift from traditional to modularized education is often associated with a change of mindsets from teacher-centered to student-centered education. The course designers/instructors, rather than thinking about the presentation of the course content, have to consider the students' learning paths through the content from the students` perspective. This means considering what students' needs might be and

how to arrange or organize the modular courses to make it easier for students to find and position themselves in their chosen learning trajectory.

From the literature, we have identified issues related to modularization, and we have categorized them under three main categories: instructional activities and learning materials for modular courses; assessment procedure; and supporting systems needed within modular systems. Under these three categories, according to the experiences reflected in the selected papers, we have put forward the important issues required in terms of what kind of support students need in a modularized system and what designers might want to consider when modularizing a course.

To put it differently, we consider that effective connections should be made (1) (starting with student prior knowledge brought to the module) within modules to help students develop a coherent learning strategy; or (2) between modules to link the learnt to other modules, and hence to develop their own study path towards their desired study goals and ambitions. This can be done by relating the learning goals (of each module) to the instructional activities and learning materials (digital or non-digital) of the modular learning environment, and further to the assessment procedures within each module – all the time considering the issues we highlighted from our review. The supporting systems needed for such a set up are manifold (e.g. blended systems). However, in our view it is crucial to also provide support for the teachers, as designers of the modularized courses, both in terms of materials resources as well as professional development.

As our next step, we plan to develop a framework consisting of guiding questions for the course designers or instructors to ease their period in the adaptation and implementation to the modular systems.

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ACTIVE LEARNING – HOW TO PROMOTE IT?

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ABSTRACT

Nowadays, learning occurs increasingly in online or blended learning environments. This can cause challenges for learners. Digital learning possibilities require i.e. self-regulatory skills such as time management and monitoring and controlling learning behaviour. According to literature, students with self-regulatory skills are typically the active ones and they are able to control their learning behaviour in different ways. Designing learning activities that are meaningful for the students can stimulate self-regulated learning and engagement to the studies. Hence, developing instruments that promote students' self-regulated learning, is considered important.

This study contributes to the discussion of promoting active learning of engineering students in online and blended learning setups. Active learning is discussed from the perspective of engineering mathematics and physics courses. The study applies Zimmerman's [1] social cognitive model of self-regulation and presents a vast variety of instruments for promoting active and self-regulated learning. This study is a part of development process that adopted design-based research approach. The aim of this study is to provide principles for changing instructional design to promote active learning.

1 INTRODUCTION

Design-based research approach has become an important approach utilized in educational research contexts during 21st century. The approach enables building a stronger link between theoretical research and an authentic learning context by designing and testing interventions that aims to improve local educational practices [2]. In the context of this study, principles of design-based research were utilized

when linking theory of self-regulated learning and active learning methods in authentic learning context. This study is a part of a larger development process reported in [19].

Putting emphasis on such instructional methods that promote students' own activity has become important in engineering studies. Mathematics and physics are subjects in which learning requires students' engagement and own activity. Self-regulated learning is one of the most important areas of educational research and it is also often connected with students' learning engagement and activity [3]. This study discusses promoting active learning and self-regulated learning in engineering mathematics and physics courses. In this section, concepts of active learning and self-regulated learning are presented. Self-regulated learning is discussed from the perspective of Zimmerman's [1] social cognitive model of self-regulation.

1.1 Active learning

Broadly speaking, active learning covers a variety of instructional methods which engage students as active participants. Hence, active learning is anything but passive listening of a lecture. Prince [4, p. 223] defined active learning as "any instructional method that engages students in the learning process". Thus, engaging and activating students during their learning process are the core principles of active learning [4].

In science, technology, engineering and mathematics (abbreviation STEM), examples of active learning methods are i.e.: simulation, demonstration, laboratory work calculating, learning from educational videos, group discussion, taking online exercises, self-assessment and peer instruction. Such instructional methods promote students' own activity and taking responsibility of their own learning process. Instead of passively listening to a lecturing, students actively do learning activities and process information in various ways. In mathematics and physics much of studying includes understanding of mathematics/physics concepts and procedures, which require active learning from students.

Different studies have highlighted benefits of active learning methods. Freeman et al. [5] carried out a meta-analysis of 225 studies that had reported course scores and passing rates in STEM courses and they compared results of studies between traditional lecturing method and active learning methods. Their analysis indicated that using active learning methods can increase passing rates and course scores. Especially, they found that active learning methods have great benefits with small groups, but it is effective for all group sizes. Similar positive effects have been found also in other studies [4, 6, 7].

1.2 Self-regulated learning

Active learning can be promoted in both traditional classroom setting and online learning environments. When learning activities occur in online learning environments, it requires from learners i.e. time management, attention focusing, capability to select, use and apply effective learning strategies and ability to control and monitor their own learning process. In other words, it requires self-regulatory skills. Such self-regulatory

skills are often connected with active learning. Research has shown that when mastering own learning process, learning outcomes are typically better [8, 9].

Different theoretical models for self-regulated learning have been developed such as Borkowski [10], Efklides [11], Pintrich [12], Winne and Hadwin [13] and Zimmerman [1], for example. Social cognitive perspective is the most widely used theoretical perspective for self-regulated learning [14]. This study uses Zimmerman's model [1], which relies on the social cognitive perspective of self-regulation.

1.3 Zimmerman's model of self-regulation

From a social cognitive perspective, self-regulated learning is a context-related cyclical process [1, 15]. Based on Zimmerman's perspective, a self-regulated learner uses the feedback from prior learning efforts to monitor and adapt his/her learning behaviour, while occurring learning tasks [16].

Zimmerman's self-regulated learning model (see *Fig. 1*) has three phases: forethought, performance/volitional control and self-reflection, each divided into two sub-processes.

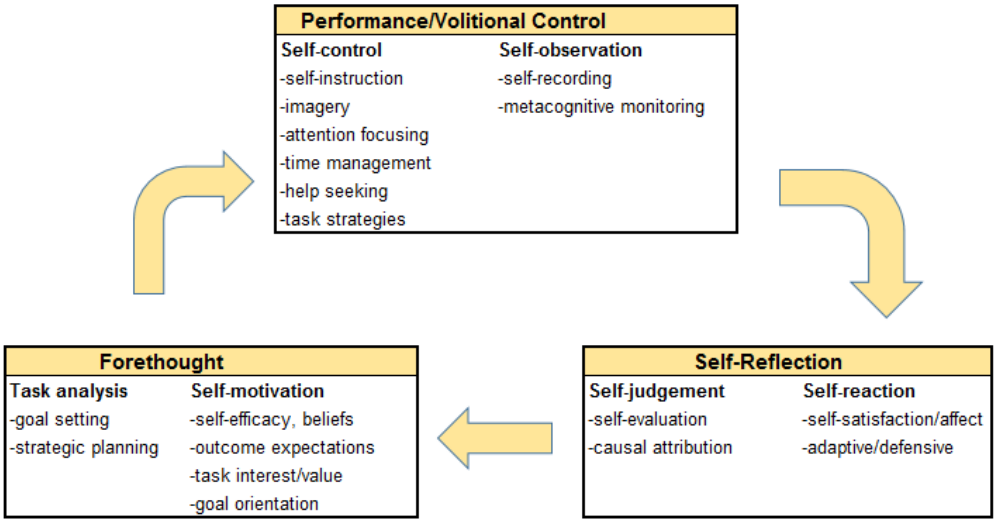

Fig. 1. Zimmerman's model of self-regulated learning [1, 15]

During the forethought phase, a student sets goals for a learning task and selects proper learning strategies. Self-motivation components such as e.g. self-efficacy beliefs, outcome expectations and task interest usher the process and selection of strategies. During the performance/volitional control phase, a student executes the learning task at hand. A self-regulated student monitors, observes and controls his/her learning behaviour, uses proper time management and seeks help while completing the learning task, for example. In the third phase, self-reflection phase, a self-regulated student self-evaluates his/her performance. Attributions are student's beliefs about the reasons of success or failure. Self-reactions that are caused by success/failure can be

positive or negative and the reactions can influence student's future motivation and performance [1, 17].

2 PROMOTING ACTIVE LEARNING

Self-regulatory skills are not mental abilities but rather they are task related skills. Students can learn to become a self-regulated learner [1, 18] and an instructor can promote students' self-regulatory processes. As active learning and self-regulated learning are often connected with academic achievements, promoting self-regulated learning is one perspective for enhancing students learning in engineering mathematics and physics [19]. The following chapters introduces methods and instruments for promoting active learning in engineering mathematics and physics courses especially from the perspective of self-regulated learning.

2.1 Different lecture structures

Research has shown, that students can maintain their attention only about 15-20 minutes during lectures [20, 21]. Hence, putting emphasis on instructional design that promotes students' own activity is important.

One way to support maintaining students' attention during in-class sessions is to vary lecture structures in a meaningful way. Active learning can be promoted with different lecture structures, for example by varying the activation tasks and lecturing. *Fig. 2* demonstrates examples of different types of face-to-face lecture structures that promote active learning.

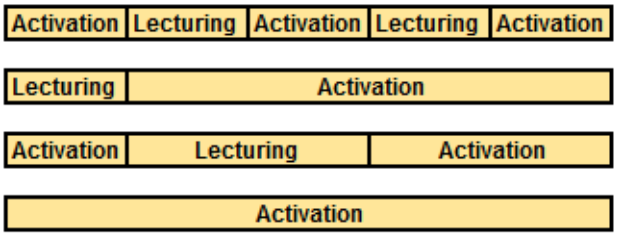

Fig. 2. Examples of different types of lecture structures

A lecture that promotes students' active learning can for example start with activation task and continue with lecturing and activation tasks. A lecture can also be fully activating. Following presents examples of more specific instruments for promoting students active learning in engineering mathematics and physics before, during and after lectures.

2.2 Instruments for promoting active learning

In engineering mathematics and physics courses, students' own activity is important to be able to learn abstract concepts, procedures and problem-solving skills, for example. *Fig. 3* presents different instruments for promoting students' active learning

from the perspective of self-regulated learning [applied from 19]. Different instruments are connected with Zimmerman's self-regulated learning cycle.

In the forethought phase, a student sets learning goals and selects learning strategies. Self-motivation typically controls these actions. Students' strategic planning and goal setting can be promoted by i.e. providing clear assessment criteria for course or learning task, setting detailed weekly learning goals and giving specific learning goals for the course. For example, competence-based assessment criteria for different grades help students to recognize, what are the learning outcome expectations of the course, which naturally influence on students' learning goals [17].

Motivation consists of different components. Students' outcome expectations, self-efficacy beliefs and task interest are examples of such components that influence learning motivation [22]. From this point of view, for example a survey at the beginning of a course that helps students to recognize, how they are learning and studying, can promote students' motivation and support self-regulated learning.

Self-efficacy beliefs are one of the components that influence student's learning motivation [22] and are strongly task related. When a student experience learning task as useful or valuable, it typically promotes student's learning motivation towards the learning task at hand [23]. In physics, demonstrations, measuring exercises supporting theory, practical laboratory exercises and different types of exercises from easy to demand, are elements of instructional design that students typically experience as useful. Hence, these kinds of elements can contribute student's learning motivation that are connected to successful learning outcomes.

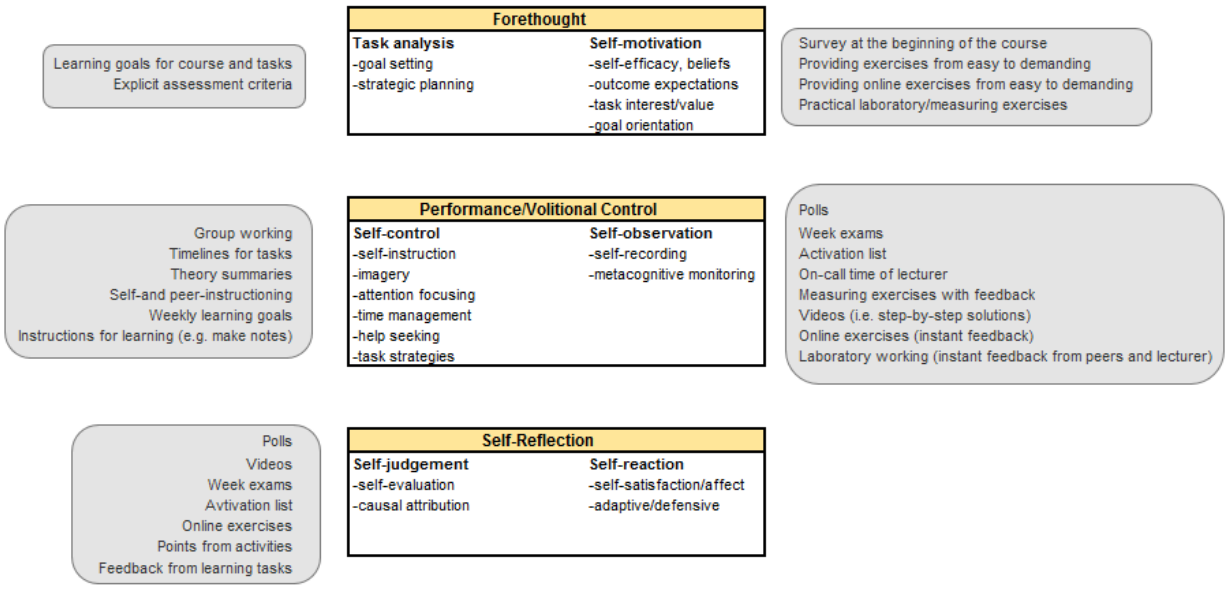

Fig. 3. Examples of elements for promoting active learning

The next phase in Zimmerman's cyclical process is performance phase, when a student executes the learning task and uses the strategies that he/she selected in the forethought phase. Performance phase includes self-control and self-observation classes.

Group working and self/peer-instructions are elements that can contribute students' self-control. If an instructor provides specific timelines for different learning tasks and gives learning goals at weekly level, these can help students to focus their attention, promote help-seeking and enhance time management, all elements of self-control. Also, instructions for learning, such as make notes about the video lectures or keep learning diary about laboratory working, are instruments that promote students own activity and self-control.

A part of the performance phase in Zimmerman's model is self-observation, when a student tracks and monitors his/her learning behaviour systematically [16]. E.g. different types of polls and week exams activate students and can provide valuable feedback to students about their personal performance and help their self-observations. Such instruments are online exercises and short learning videos, as well. These all can contribute students' learning by giving instant feedback about individual student's current performance. In subjects such as mathematics and physics, where a lot of learning is calculating exercises, instant feedback is of great importance in the development of students' conceptual understanding and procedural fluency.

Third phase in Zimmerman's model that occurs after learning effort, is self-reflection. This phase includes self-judgement and self-reaction classes. Student's performance related self-reflections typically influence the forthcoming forethoughts (i.e. outcome expectations and self-efficacy beliefs in the future) completing the cyclical nature of Zimmerman's self-regulated learning model [16]. In this phase, a student evaluates usefulness of selected strategies and reasons for good performance or possible failure [24]. In this phase, a student typically evaluates, whether the success was due to effort or whether the lack of effort or lack of ability cased the performance failure [16]. The attribution style a student has, influence on which emotions, positive or negative, a student experiences regarding to performance. This naturally can affect student's motivation in the future [17].

Figure 4 shows an example of student self-evaluation tool used in physics learning. Each week the students filled in a detailed online self-evaluation form of their mastery of the week's topics. The form is adopted from the work of Peura [25]. The table was visible to all students. Therefore, only nicknames were used on the table. In *Fig 4* the first weeks of the table are shown. Students typed a letter to the cells according to their perception of the mastery of the topics and the cells were then coloured automatically accordingly:

a) I have learnt this so well that I could teach it to my peers.
b) I feel I understand this topic.
c) I think I have understood this partially, but partially it is unclear.

d) I need more practice to understand this.

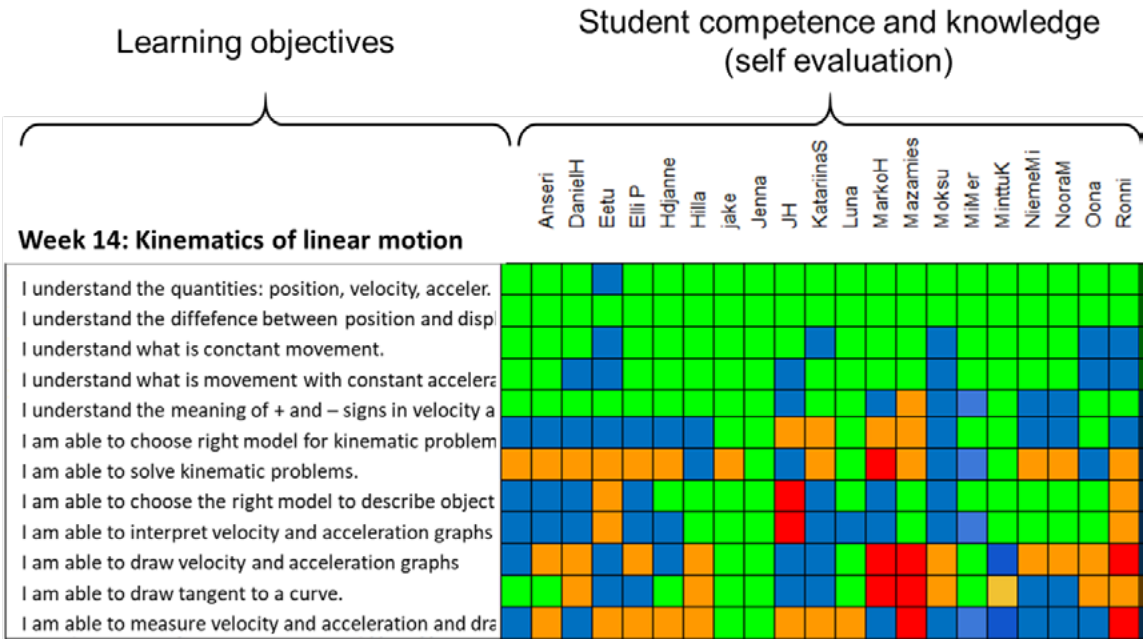

Fig. 4. An example of an online student self-evaluation form adapted from [25].

Different types of instruments that provide feedback about student's progress and performance give to a student an important information for self-evaluation. Such instruments are e.g. polls, videos, week exams and online exercises that help students to evaluate and reflect their understanding and learning. Also, assessment instruments such as points from week exams and activation list (list of exercises) give students resources for self-evaluation. Different form of feedback also serves adaptive students that learn from their mistakes and modify their learning strategy in the future.

3 SUMMARY

This study discusses promoting active learning of engineering students in engineering mathematics and physics courses. The study gives examples of methods and instruments for activating students from the perspective of self-regulated learning. Students that have self-regulatory skills are typically active and engaged to their studies. These students are also able to control their learning behaviour in different ways. With proper instructional design, it is possible to develop learning activities that are useful and meaningful for the students, which can stimulate self-regulated learning and engagement to the studies. This study is a part of a larger development process that adopted design-based research approach [19].

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TEACHING TRANSVERSAL SKILLS IN THE ENGINEERING CURRICULUM: THE NEED TO RAISE THE TEMPERATURE

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ABSTRACT

Engineers and architects today are dealing with great social, technical and environmental complexities, and the demand for having broadly educated holistic engineers will only continue to grow in the future. Being able to manage and lead diverse teams, understand complex, interdisciplinary systems and solve open-ended problems across and beyond different subjects is expected from the next generation of graduates.
With the aim to understand how the future graduates are educated to cope with such complexities, we developed a tool to map out the course curricula and examined the extent to which transversal skills are taught at a leading technical university in

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Europe. Using MATLAB, we have conducted an exploratory analysis, and this concept paper offers the outcomes of analysing course descriptions of bachelor and master programmes throughout the academic year 2018-2019. By presenting the results in a visual form of a heatmap, we have examined at which moment throughout the curriculum and how frequently are transversal skills included in the teaching objectives.
The results indicate an overall gap between teaching transversal skills at both BA and MA level, but also a difference in teaching transversal skill in mandatory and optional courses. Furthermore, throughout the curriculum we observed a significant lack of some critical skills, such as those connected to ethical reasoning. This project opened valuable avenue to deepen the discussion regarding teaching and learning of transversal skills, as well as the structural changes that need to be considered in the education of the engineers and architects in future.

1 INTRODUCTION

1.1 Background

It has been evident for a while that future engineering graduates will face challenges that go beyond the borders of their discipline [1]–[3]. Global and local dilemmas [4] are demanding high levels of transversal skills. The worldwide pandemic at the beginning of 2020 that further aggravated social, health, and economic issues has proven it even more strongly. Thus, it is both from the perspective of emerging problems and from the perspective of labour market needs, that the 21st century will not be able to rely on the traditional educational directions within the engineering field, and therefore needs a better balance between technical and transversal skills [3], [5]–[7].
This concept paper reveals results of a projection analysis based on a mapping project which examined the teaching objectives of transversal skills at the École polytechnique fédérale de Lasuanne (EPFL). Contrasted and analysed against the evidence from literature, we examine the results by looking at different possibilities for change as well as by inciting new questions to the discussion tables.

1.2 Theoretical underpinnings

As world knowledge doubles every 10 years, the demand for better and more comprehensive educational strategies grows. In perspective of the future of engineering it has never been more necessary than today to have future graduates ready for managing, leading and understanding complex interdisciplinary systems [3], [8]. The next generation of engineers will need to be educated as “holistic engineers”, flexible and adaptive to bring solutions by combining engineering expertise within domains of technology, law, public policy, sustainability, arts, and so on [3]. While there is no lack of agreement that the appeals for high levels of transversal skills across the engineering curriculum are justified, the gap in achieving it still continues to linger [5], [6].
Brunhaver et al. [7] point out to the dangers of having a naïve presumption that all engineering careers go through a homogenous track and require a similar balance of

technical and transversal skills. Through their research, they brought a better understanding of the vast array of different early career engineering profiles, emphasising the importance of problem solving and analytical skills, together with communication and business acumen as prevalent for those choosing managerial and consultant profiles. Furthermore, the issues in acquiring these skills are oftentimes seen in a very basic, technical way. For example, there is an assumption that communication skills in engineering are based on writing technical reports and providing oral presentations. Yet, in practice, engineers can spend up to 60% of their work-related communication in interaction with others, often from different backgrounds and cultures, for which they require good listening and collaborative skills [9]. In addition, effectiveness of transversal skills acquisition is rarely evaluated beyond student self-reporting [5], implying that it is less valued than the technical subject-related knowledge and skills.

Overcoming these gaps in the first several years of an engineer's early career is time consuming, and, in most cases, avoidable [9]. Torres et al. [6] found that some of the general issues in pedagogical re-planning of the curriculum are indeed connected to excessive lecturing, lack of active learning, reduced engagement and poor motivation. Furthermore, some transversal skills, such as those related to ethics are frequently placed as optional courses rather than implemented as part of the core teaching. This is oftentimes connected to the fact that engineering teachers feel ill equipped and unprepared to deal with content related to ethics in engineering education [10]. Assessment, and more specifically lack of formative feedback, was identified as another large issue. Not being able to adequately address transversal skills from the pedagogical point and assessing them in a manner that brings out the value of the skills, has been a dilemma for many teachers and institutions.

It can be argued that skill and knowledge gaps exist because of the "necessarily generic nature of university education and the specific requirements of individual job roles" [11, p. 297]. Furthermore, the majority of engineering courses are embedded in a single discipline while trying to prepare graduates for an interdisciplinary engineering practice [11]. In addition, transversal skills are rarely taught in a way to glue the different disciplines together. This goes along and notwithstanding the fact that learning transversal skills is a joint venture of teachers' instructions and students' engagement, in which educational institutions have an important role to provide the impetus and raise the profile of transversal skills so that they are as significant as the technical ones [5]. Leaning on this, it is necessary to adequately and continuously examine how engineering curricula is prepared and delivered, as well as how institutions encourage the value of transversal skills through different aspects of student journeys.

1.3 Context

This concept paper focuses on the analysis of intentions to teach transversal skills in bachelor and master courses at EPFL. The mapping of the intentions was done by using the official course descriptions and combining the information to understand which skills are represented with what frequency and intensity, at which particular

time across the entire curriculum and across all of the EPFL faculties. The aim of this mapping project was to understand the prevalence of the skills and potential gaps, as well as to identify examples of good practice.
At EPFL, each course description has several parts including a description of the content, exam type, semester of delivery, and learning objectives. The learning objectives are divided into two parts, (1) the subject related knowledge and skills and (2) the transversal skills course objectives. When designing their courses, teachers can select from a list of 32 different transversal skills that can be integrated into their subjects. Each teacher can "drag and drop" as many skills as they plan to teach in their courses. This means that a course could have between 0 and 32 skills included in their learning objectives.
The list of the 32 transversal skills is divided into 5 skill-families: (1) Communicate, process, manage, and generate information, (2) Personal effectiveness, (3) Project management, (4) Working in the society, and (5) Working in groups and organisations. The list was created in 2012-2013 through a process of institutional consultation led by the experts in EPFL's Centre for Teaching Support, and taking into consideration the main theoretical and empirical trends at the time.

2 METHODOLOGY

2.1 Data

Analysis involved a total of 929 course descriptions found within 13 bachelor and 25 master programmes during the academic 2018-2019 year. This included 351 bachelor courses, 475 master courses, 75 minor courses, 22 master project courses and 6 other courses. From the available data imported from the course descriptions, we used the information on transversal skills, independent of whether a course is obligatory or optional, the level at which it is taught (in semesters from BA1 to MA4), the number of students per course and to which faculty the course belongs.

2.2 Procedures

To analyse the data, we used Microsoft Excel and MATLAB. The two were used simultaneously in order to validate the imported information and support the development of categories. Furthermore, we used MATLAB to generate heatmaps in order to visually present the large amount of data.
The analysis consisted of measuring and visualising by displaying heatmaps of two main distributions:

1. The distribution of the number of courses proposed to EPFL students, across the curriculum and for the 32 transversal skills that can be selected in the course descriptions,
2. The distribution of the number of students participating at each of these courses, across the curriculum and for the 32 transversal skills that can be selected in the course descriptions.

It was necessary to prepare both distributions because bachelor level courses include more students, while at the master level there are overall a greater variety of specialised courses taught. Therefore, looking only at the number of courses and

neglecting the number of students, would give an incorrect representation of the situation.
Using MATLAB, a graphical user interface (GUI) has been developed in order to facilitate the selection of data to visualize in the heatmaps. This GUI allowed for selecting sections of interest, for instance specific tracks of students, for example mathematics or chemical engineering. This means that by selecting specific sections only the data related to courses proposed to students of the selected sections are displayed in the heatmap.

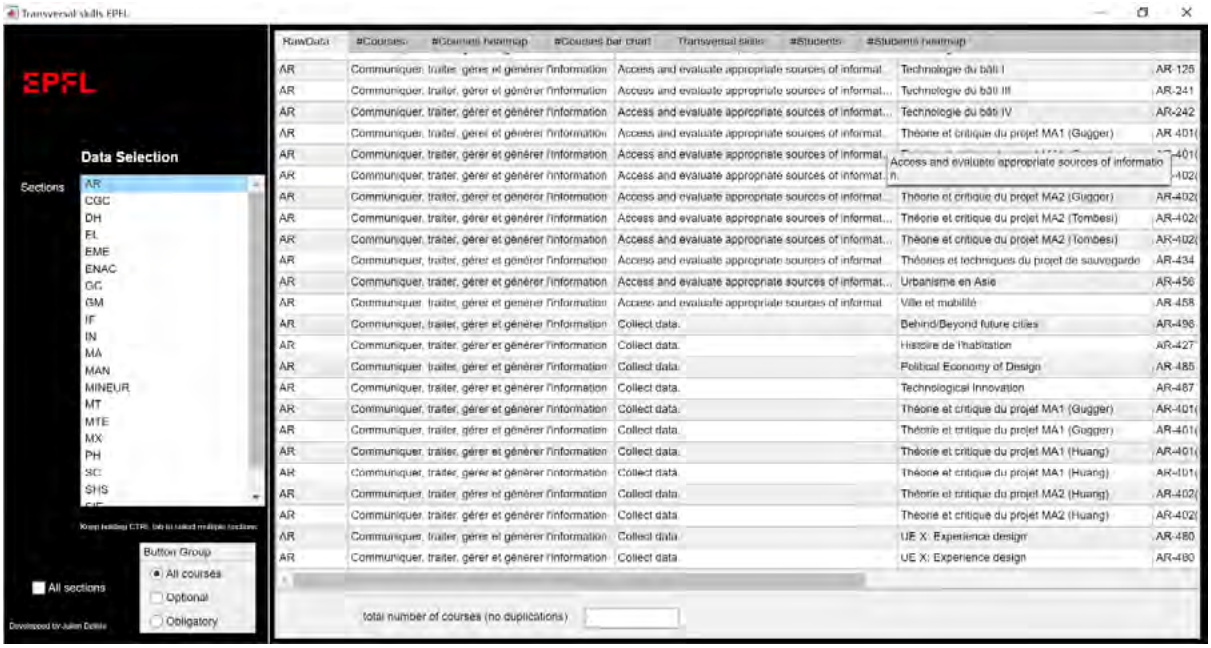

Fig. 1. GUI filtering raw data and displaying the hear maps accordingly. Data can be filtered by selecting one or multiple sections. Moreover, obligatory, optional or both can be selected to filter data

MATLAB software has a specific feature that allows for categorical data to be used, which was one of the main reasons for selecting it as a tool for displaying results. This helped in reducing the maximum computational resources required to update and visualise the data when the selected section is modified, as well as to successfully compute accurate heatmaps.

2.3 Limitations

While analysing the data, we noticed several potential limitations. First of all, we need to emphasise that the course descriptions highlight only the intentions and not necessarily what is actually being taught by the teacher nor what is being learnt by the student. Hence, the analysis addresses merely the intended learning objectives and not the learning outcomes. Secondly, the analysis points out the intended learning objectives at a fixed moment in time. This goes to say that the course descriptions highlight the intentions before the semester starts, and it is important to take into account that this may change in practice by the end of the semester. Another limitation is that we did not survey teaching staff to question how they interpret the inclusion of certain skills in their course description. In other words, we

do not know whether they actively teach these skills or whether they assume students will learn these skills implicitly during their courses. In addition to this, we must assume that there are skills which might not be included in the course descriptions but are taught by teachers even unconsciously. And, finally, some courses are mentioned as being part of a minor ("plan mineur") but might not be displayed in the heatmaps because of missing information. This means that the total number of courses displayed in our analysis at the master level might be slightly lower than the actual numbers. Being aware of these limitations supports a better interpretation of the results and leads to more adequate recommendations for further actions.

3 RESULTS

3.1 Transversal skills throughout the curriculum

Across all courses and levels, we have registered a total of 5182 transversal skills in the course descriptions. Table 1 provides information of the total number of transversal skills at different levels and between obligatory and optional courses.

Table 1. Distribution across levels

	BA1-BA6	MA1-MA4
Obligatory courses	835 (48%)	575 (16.5%)
Optional courses	872 (52%)	2853 (82%)
Uncategorised	0	47[2] (1.4%)
Total	1707 (100%)	3475 (100%)

Looking at the total numbers, there is a noticeable discrepancy between bachelor and master courses, especially for the optional courses. However, it is good to keep in mind that while the number of courses is higher at the master level, the number of students per course is higher in the BA courses, especially in the first year. At the master level the course-student ratio becomes smaller yet more specialised and optional. This explains some of the reasons behind having higher numbers in optional MA courses.

Computed as a heatmap, Figure 2 presents the prevalence of the 32 transversal skills at each level, starting from BA1 to MA4.

[2] At master level there were 47 entries which were not categorised as either obligatory or optional

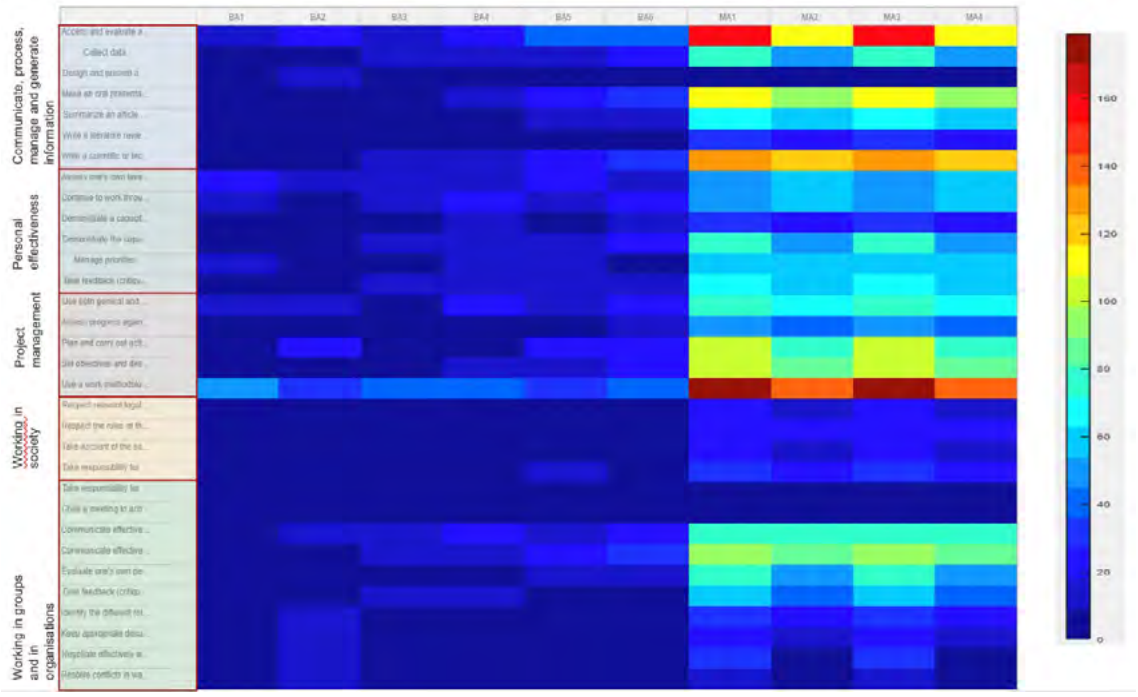

Fig. 2. Heatmap of specific transversal skills per course institution wide

As we can see in Figure 2, there is a clear horizontal gap between the bachelor and master level. The second evident observation is vertical “cold” area around the “Working within society” family which indicates the lowest number of taught skills. Even though it is already possible to draw conclusions regarding the distribution of the transversal skills in general, the representation of this heatmap reflects the number of courses taught, and not the number of students following these courses. This is relevant to take into account, since some BA courses have up to 200-300 students while some MA courses can have as low as 1 student. Hence, a heatmap of the total numbers of students attending the courses has been computed in order to complement Figure 2.

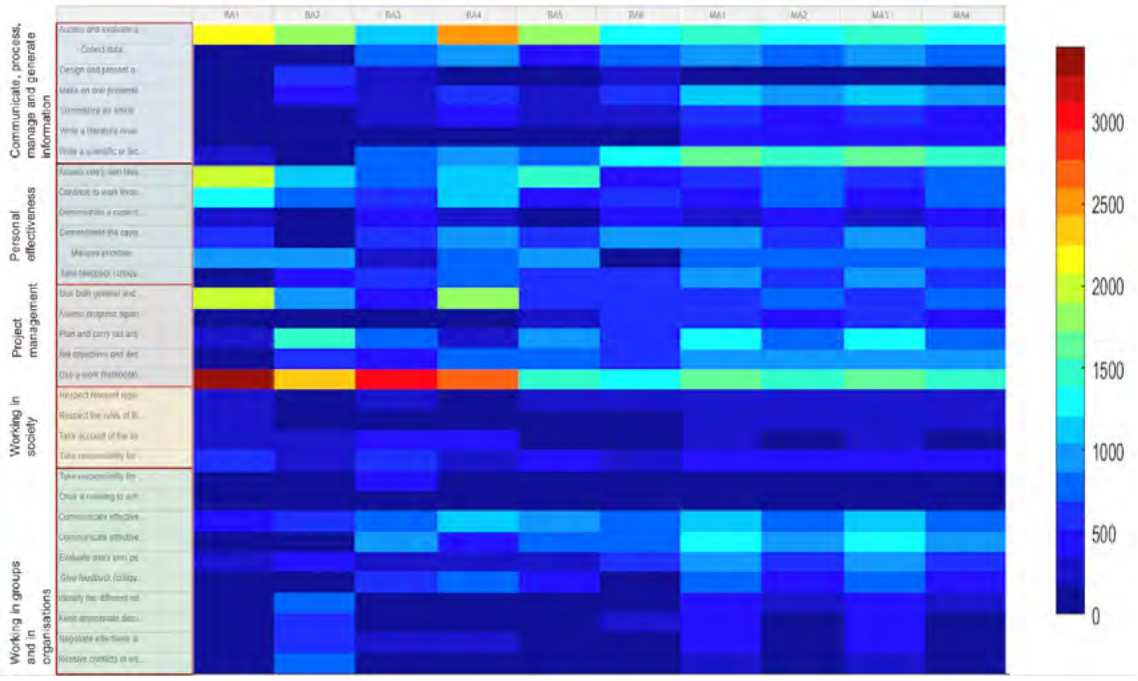

Fig. 3. Heatmap of specific transversal skills per student institution wide

What we can additionally learn from looking at Figure 3 is that since there are greater numbers of students at bachelor level, the overall curriculum of transversal skills does reach more students than represented solely by courses. We can observe that most represented skills are “Use of a work methodology appropriate to the task”, “Access and evaluate appropriate sources of information” and “Write a specific technical report”. This comes in contrast with the least represented skills which relate to already mentioned “Working in the society” family, including “Chair a meeting to achieve a particular agenda, maximising participation”, “Take responsibility for health and safety of self and others in a working context”, “Take account of the social and human dimension of the engineering profession”, as well as those in other skill-families such as “Resolve conflicts in ways that are productive for the task and the people concerned”, and “Design and present a poster”. At the bachelor level “Respect the rules of the institution in which you are working” and “Write a literature review which assesses the state of art” are additionally noted as low.
To complete the overall analysis, we computed a heatmap according to whether the courses are obligatory or optional. This allowed us to see the extent at which students receive obligatory courses that include transversal skills, and how much of it is left as an option.

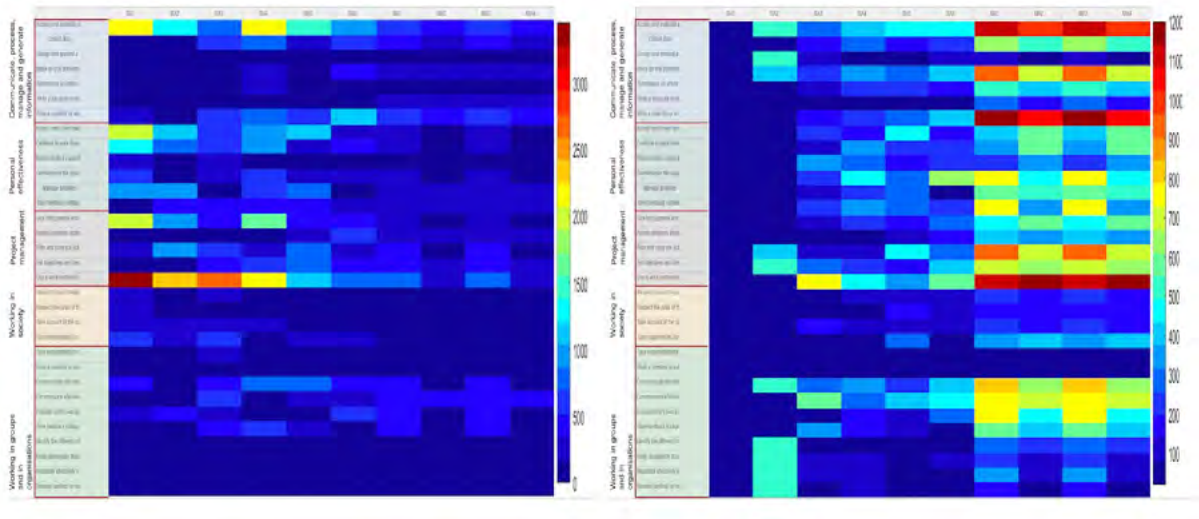

Fig. 4. Heatmaps of specific transversal skills per students in obligatory (left) and optional (right) courses

As we have observed in Table 1, optional courses are numerous, especially at master level. Looking now at Figure 4, we can see that this occurrence significantly influences the overall trend of teaching transversal skills. As much as skills in families of “Personal effectiveness” and “Project management” are relatively well covered in obligatory curriculum at bachelor, we can clearly note a gap in several of the skills in the family of “Working in groups and organisations” and, the already mentioned, “Working in the society”.

Finally, we have noticed a large discrepancy when analysing data from specific sections and, most importantly when looking at the Social and Human Science (SHS) programme. The SHS is an integral cross-curricular programme offered at Bachelor and Master level, and while courses of SHS are often provided as optional courses, they are required for students at certain levels. When analysis the data we noticed that SHS courses have the highest level of transversal skills, compared to any other courses taught by individual sections. Hence, since the SHS are cross-curricular, we computed two heatmaps to understand the difference between courses taught within a section with and without SHS.

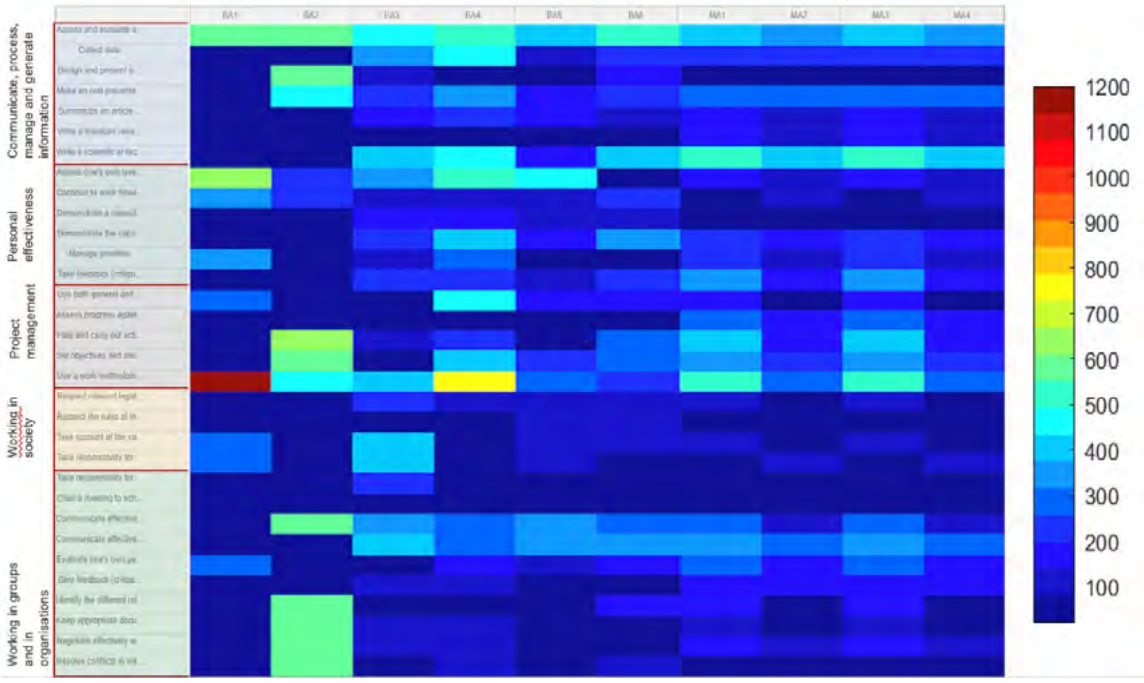

Fig. 5. Heatmap of specific section including Social and Human Sciences (SHS), across complete curriculum

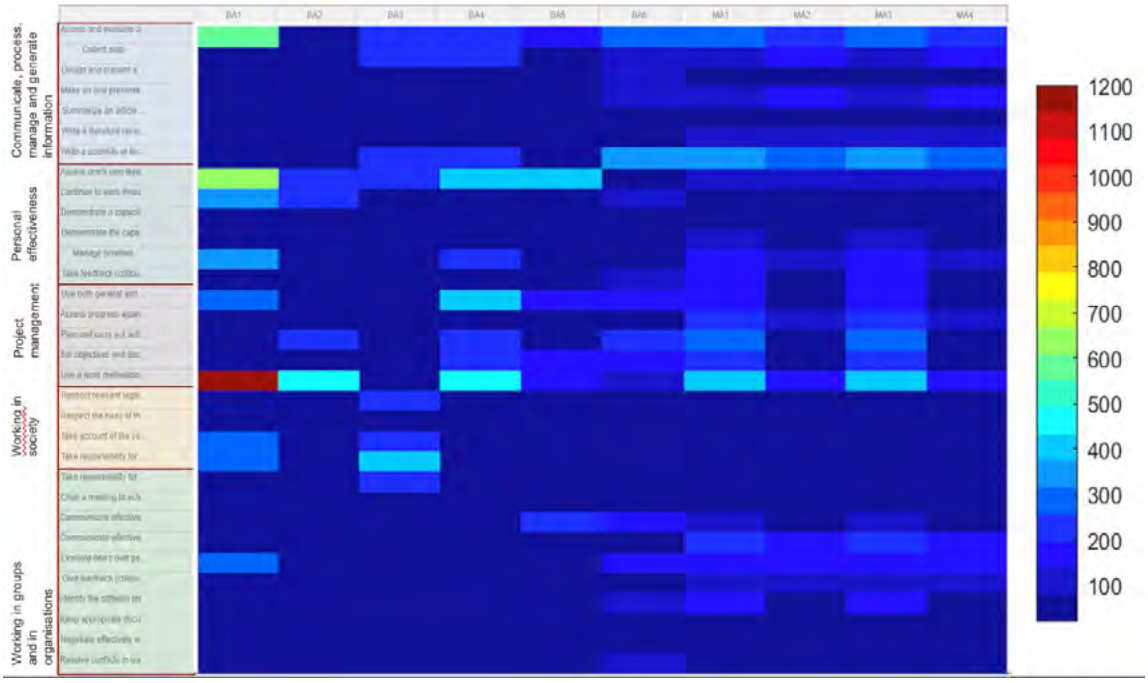

Fig. 6. Heatmap of the same example section (Fig. 5) not including SHS

In the two figures, Figure 5 and Figure 6, we present an example of a randomly selected section at EPFL and how the heatmaps look when SHS courses are included and when not. What we wanted to illustrate with this comparison is the mere fact that the main curriculum of the section (Figure 6) significantly lacks in teaching transversal skills. Furthermore, we also wanted to state that having SHS

programme (Figure 5) to supplement this gap helps in improving the picture and offering students chance to learn transversal skills.

3.2 Discussion

One of the first points that this analysis brings forward is the existence of a wall between teaching transversal skills at bachelor and master level. This might be problematic, for several reasons. One could be that not all bachelor graduates continue their studies at master's level, hence their transition to their early career might feel difficult due to the need to compensate for the lack of the skills [9]. It is also quite common that bachelor graduates are more likely to engage in a wider variety of career paths, hence the necessity of having stronger transversal skills is even higher. Many of the transversal skills are deemed as a basis for any workplace, and consequently they should serve as the foundation for the more domain specific skills [5], [6], [12].

On the other hand, the analysis surely corroborates that most of the subjects embedded in the engineering curriculum are oriented towards technical skills, they are monodisciplinary and they follow quite a generic approach, especially at the bachelor level [11]. Considering this, we do question the meaning of a specific transversal skill within the engineering curriculum and profession [7], [9]. By this, we both refer to the necessity to understand for example what is the scope of communication skills for an array of engineering professions today and tomorrow, as well as what can be the gradual acquisition of these skills and how can it be taught in a steadily progressive way. This said, a specific skill, such as problem solving or leadership, needs to be taught at all levels with a different intensity and depth.

Furthermore, the idea of teaching transversal skills as part of SHS programme is a helpful addition to provide skills to more students, however it is a patchy solution. Teaching transversal skills outside of the main engineering curriculum might offer an idea that these skills are second-grade in comparison to the more technical ones taught in the compulsory courses. Additionally, if the transversal skills are not reflected in the content, issues and problems posed by technical courses, their applicative value might be lost too. While battling this problem might involve a huge amount of efforts in equipping engineering teachers with necessary skills [6], [10], lack of motivation and reduced engagement can no longer stand in the way of bettering engineering education.

Finally, the analysis did bring up the question of institutional challenges when attempting to teach transversal skills [6], in which the question of planning the curriculum, training teaching staff as well as assessment skill mastery play a significant role. It is worthwhile considering what sort of curricular model is most likely to provide a stronger coverage of transversal skills and how institutions can support raising the profile of these skills [5]. In addition, the analysis does indicate the need for further exploration both in terms of understanding which are the most important transversal skills and how they should be taught in order to holistically prepare engineering graduates for complexities of their future jobs.

4 SUMMARY

The lessons learnt through this projection analysis are truly multifaceted and can be extended to a number of discussions related to the present and the future of engineering education. While we point some of them in this concept paper, our project continues to go deeper by examining the examples of good practice and showcasing different models of teaching transversal skills across the curriculum. Understanding pedagogical cases that bring the temperature up in the heatmap, as well as exploring what makes the curriculum cold, will help in dissecting how engineering education can be re-shaped to better prepare the holistic engineers for tomorrow.

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DEVELOPMENT AND IMPLEMENTATION OF AN E-LEARNING TOOL FOR TECHNICAL MECHANICS TO PROMOTE TRANSFER KNOWLEDGE OF ENGINEERING STUDENTS

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Keywords: *technical mechanics, transfer knowledge, e-learning, prompts*

ABSTRACT

The individual support of students in basic subjects such as technical mechanics (TM) is difficult to implement due to large and heterogeneous groups. Students tend to memorization due to the conventional teaching concept, they cannot transfer the theoretical content to unknown contexts. According to Müller-Slany (2018) every mechanical exercise, regardless of its complexity, is subject to the same solution methodology. It implies solving the exercises with a model. Reflection and transfer, the last step in the modelling cycle, are often not considered in the teaching [1]. Training the structure of mechanical exercises is a basic skill required for the last step of the modelling cycle and is therefore essential and principal for teaching.

The aim of this project is to support transfer knowledge by development and implementation of an e-learning tool that supports the individual learning process of every student by giving faults-related feedback in the form of prompts. Prompts increase problem-solving skills [2]. Furthermore, they help with the self-regulated solution process and support metacognitive reflection [3]. Faults can then be identified with the help of this extensive faults- prompts - system. By solving contextualized pre-structured exercises with differences in depth of structure the development of transfer knowledge [4] should be increased. As part of a formative qualitative evaluation, suitable prompts are developed and then the influence of the exercise format is examined in an experimental design.

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1 INTRODUCTION

Individual support for students in bachelor's basic subjects, such as technical mechanics (TM), is difficult to implement due to large and heterogeneous groups. The students have heterogeneous levels of performance, because i.a. the previous knowledge in the technical subjects varies significantly at the start of the first two semesters. Students tend to memorize, they cannot transfer the theoretical content to unknown contexts, even though they initially have a positive self-efficacy that represents a discrepancy with the actual performance.
This can be a reason for the high dropout rates of students of engineering bachelor's courses, especially in the first two semesters. Another reason can be the lack of entry qualifications in mathematics and physics. The TM requires mathematical modeling of professional interconnections in order to be able to analyze mechanical systems. A detailed competence modelling of students in the TM in engineering courses has already been carried out (cf. [5]). Results of this study show that mathematical skills of the students have a strong influence on the performance in statics.

Students hardly reflect on the learning process and modeling skills are not dominant either ([7]).
One aspect of achieving a better metacognition is to foster self regulated learning. The other way to promote metacognition, this time in a direct way, is the use of strategy training in form of scaffolding. For this approach contextualized prestructured tasks with varies depth of structure are integrated in the system. The task format at the beginning is structured very strong with many subtasks and after solving the tasks this way successfully, the students achieve more open taskformats. This scaffolding element is named fading ([9], [6]).
Metacognition is the knowledge about the own learning process, so planning, monitoring and reflection about the learning behaviour should be supported with these approaches. By reflection the own learning process students can train their modeling skills through seeing the strategy they used by solving the task.

According to Dammann [5], the basic selection of TM exercises at each university is the same, the task types are similarly structured. In statics, the following topics are always relevant in teaching: resulting force and moments, support reactions, trusses, internal forces and centre of gravity.
According to Müller-Slany [1], every mechanical exercise regardless of its complexity is subject to the same solution methodology. This describes solving the exercises as modelling. Figure 1 shows this schematic structure of a mechanical exercise based on the modeling cycle according to Müller-Slany.

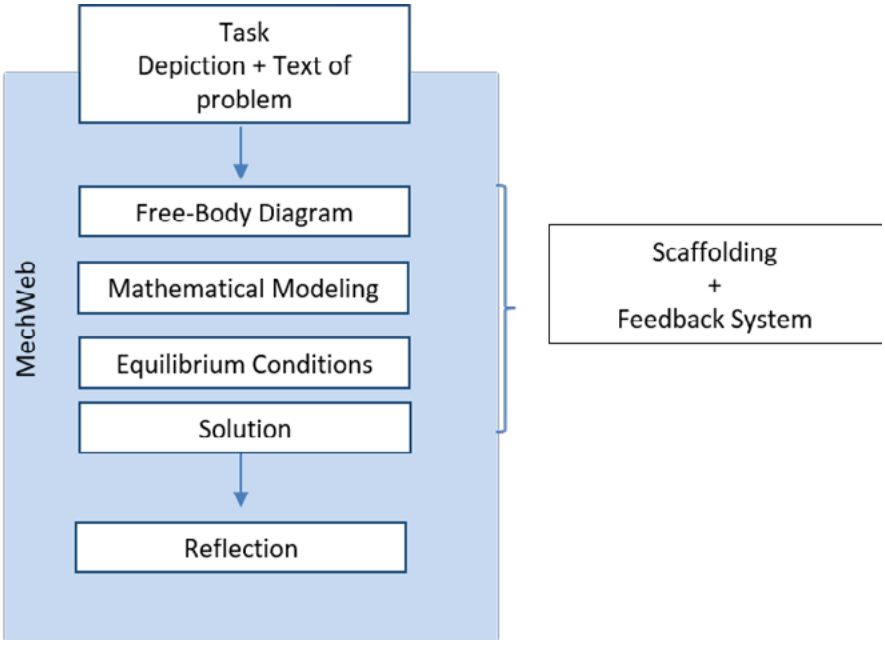

Figure 1: Structure of mechanical tasks (cf. [1])

The practice of this modelling showed in Figure 1, i.e. the schematic solving of tasks, takes a lot of time in teaching. Exam results show that this model identification and modelling itself is often not implemented in teaching.

The learning outcomes within the framework of the TM are often only oriented towards the pattern-recognition and repetition. Reflection and transfer, the last step in the modeling cycle, are therefore often not reflected in teaching [1]. Training the structure of mechanical tasks, i.e. modeling, is a basic skill required for the last stage of the modeling cycle and is therefore essential and principal for teaching.

There are currently only a few eLearning tools in the TM, and none of the existing offers include one that specifically supports this pattern-recognition and then independent modeling. A comprehensive market analysis in 2018 shows that there is no e-learning tool that requires an individual, interactive approach, specifically discloses and trains the scheme of mechanical tasks or helps with the independent fault analysis. The existing tools use formats such as multiple choice or the entry of a final solution such as Lon Capa or usable for reviewing, the drawing of systems to get a result with automatic calculation of the demanded dimensions such as RatzFatz at the University of Wuppertal.

2 METHODOLOGY

With the eLearning Tool developed in this project, it should be possible to support the individual learning process of the students better by promoting the modeling in solving mechanical tasks and focusing on the independent fault analysis.

With regard to these aims, the focus is on the one hand on showing the schema, i.e. the model, and on the other hand on the transfer of this schema to unknown contexts for better problem solving skills.

2.1 STUDY APPROACH

The exercise concept to be developed based on two main aspects: on the one hand there should be integrated scaffolded tasks to show and train the scheme of the exercise by dissolving the given task structure through many guided subtasks in the course of processing and on the other hand a feedback-system with fault-related prompts should be implemented. The influence of both interventions (scaffolded tasks and feedback-system) on the modelling, i.e. pattern-recognition and transfer, should be examined in this study approach.
Hence, the following research questions are to be investigated:

1. What influence does the scaffolding have on the modeling?
2. What influence does the feedback system have on the modeling?

2.2 METHOD AND DESIGN

The effects of the two mentioned interventions have to be examined individually, so in this study a 2x2 design is chosen. Figure 2 shows the test composition.

		Scaffolded Tasks	
		yes	no
Feedback-System	yes	Group 1	Group 2
	no	Group 3	Group 4

Figure 2: 2x2 Design

For the examination the mechanical engineering students are divided into four different groups to depict all combinations of intervention. Every group consists of ca. 30 students. The implemented exercises contain of the regular exercises which are used in lecture and exams and also of new created ones that fit to the design (contextualized tasks, similar tasks which varies in structure, context, values, etc.) and they will be adapted to prestrucutred (sub-)tasks and fault-related prompts depending on the fault type. These exercises are then made available online in the eLearning Tool. So the processing, data collection and data evaluation takes place online.
The blended learning concept contains of regular teaching and the eLearning Tool, which specifically supports the teaching on-site. A lecture will take place on-site. The exercises, which are provided via the eLearning Tool, serve as a prerequisite for the exam, so that the processing of the tasks in the eLearning Tool is ensured. All

students have to submit the exercises online in the form of an exercise sheet. There is also a supplementary teaching exercise on-site, in which these tasks are dealt with and questions regarding to the eLearning Tool can be asked, increasing tasks are worked on and also the time in teaching can be scheduled for reflection on the tasks and results. There is also a tutorial for the students, in which they can clarify specific questions and problems with a student as a tutor at the same level.

For an independent fault analysis, to optimize performance by disclosing your own weaknesses such as basic mathematical problems, an extensive fault-prompt-system with fault-specific prompts of different levels of help is integrated. This structure enables individual detection of weaknesses for rapid performance improvement. Furthermore the heterogeneous levels of performance of the students are taken into account, because each student decides for himself which help he needs in what level of detail. The fault-related prompts helps the students with the solution process. Prompts support the students' metacognitive reflection by giving prompts themselves [3]. Studies also show that prompts train better problem-solving skills [2]. One aspect of better metacognition is to make sure a selfregulated learning. This could be achieved through the use of (the level of) prompts, videos and the number of tasks in the exercise sheets which depends on the solution quote in the individual tasks in each level of complexity. It's necessary to make sure that all students use the prompts because only then a better metacognition can be achieved ([7]).

Through parameterized tasks in the eLearning Tool, each student receives his / her own tasks, which requires independent discussion of these. Each task is structured as a learning task, it is divided into many, small sub-tasks. The students have to solve the subtasks themselves in order to stimulate the learning activity. The next subtask will not be released until the subtask has been solved successfully. The reflection, which is only considered after the solution has been worked out (cf. Figure 1), is initially neglected because solutions of (sub-) tasks is not specified in the tool.

The small-scale, scaffolded task format should support the pattern-recognition of the mechanical tasks. In the further course of processing, more open task formats can be activated, i.e. non-pre-structured tasks with significantly fewer to no subtasks. By cancellation of this small-scale system and introducing tasks with new, unknown contexts, the intention is to promote the transfer knowledge of the students [4].

All tasks of the exercise sheets are presented as 'learning cards'. The students of the group with scaffolding units get different tasksformats of different levels of complexity. With increase of complexity the number of full-prestructured tasks reduces. The task solving quote (and the use of supporting videos) regulates the number of tasks to be solved. There are three task formats integrated in the system: the closed one is the one with the most subtasks, the semi-open format is with a given free body diagram so the calculation of a target variable have to be done by

the students themselves (find the right equilibrium conditions fitting to the given free body diagram and then calculate the unknown variable). The last format is the open one, in which the students have to calculate on their on (not in the system presented) and just need to give the endsolution. For the test students have to load up their solution with a detailed solution process in moodle so that the details of schema recognition can be analyzed.
Following test instruments are developed to check the effectiveness of the intervention: Expertise test in a pre-post- format to measure the increase in knowledge and a questionnaire that contains tasks for investigation for schema recognition.

2.3 MECHWEB – REPRESENATION OF AN EXAMPLE TASK

This concept paper includes an eLearning Tool, which is structured as followed regarding to the mentioned aims and the modelling cycle showed in Figure 1:
The free body diagram of a model should be able to be implemented interactively in the system. For this purpose, node points are first drawn in the given illustration of a machine or system, at which forces or moments, external or internal exposures engage. Then forces and moments are drawn in at these node points, angles, e.g. for the calculation of components (for later trigonometric calculations), labels of forces and moments for assignment to the equilibrium conditions inserted and forces with a dependent direction drawn in. Then the three equilibrium conditions are set up, these are all dependent on the drawn free body diagram (direction specification, direction of rotation, labeling, etc.). After this subtask, the equations are transformed to unknown variables and resolved step by step, and values for the variables are given with unit and sign - depending on the free body diagram. The fault-prompt-system that can be reached via the surface mask.
When working on the individual subtasks, prompts are displayed in form of an information box, which is activated by clicking the "Hints"- button in the upper, outer menu system. This outer menu also enables the current status to be saved for flexible processing, calling up new, similar tasks and especially checking the results after each sub-task has been carried out. If the result is correct, the feedack is “correctly”, the result entry is colored green and the next subtask is activated. If the result is incorrect, the feedback is “wrong” and a specific fault is noted. For faults such as forgotten unit, wrong value, too many or too few forces plotted, unknown variable, trigonometric problems, converting problems etc. individual feedback through prompts is given depending on the fault. For this purpose, the information box with the prompts is called up and the subtask is executed again.
If no advice helps, after five failed attempts, i.e. five times the "wrong result" indication after passing through the prompts, the task is stopped with the note: Please look for help. This help can be requested online in the forum, obtained on site in the learning center at the HelpDesk or requested in the courses, especially the exercises and tutorials.

To focus on a self regulated learning all tasks have to be solved by the students themselves and they don't get the solution. So they are forced to solve the problem and think about a possible way solving the problem. When doing a failure they can choose wheter they need help in form of prompts (indirect supporting of metacognition) and in what detail they need this help (level of prompts) or they can look a video that shows a similar task solution based on the same solution methodolgy. The integrated prompts are questions to recognize the position in the modelling cycle and reflect on the problem solving process. This prompts could be reason-justification prompts or rule-based prompts ([8]) to support transfer knowledge and strategy knowledge (modeling skills). Prompts could be e.g.: What do you need for the calculation of the force?, For what intend have you done the free body diagram? What can you do with the marked forces in the free body diagram? What are relevant variables for calculation a value for variable X? What is the next step to find out the value of X?, In what relation are the marked forces in the free body diagram with your unknown variable?

3 RESULTS

3.1 PRELIMINARY STUDIES

In the winter semester 18/19 there was a qualitative, videographed study in the form of thinking aloud with five students. Results have shown that the heavily scaffolded (sub-)tasks enable the specific detection of problems. The differentation between faults based on mechanical problems and the ones based on mathematical problems could be identified clearly. So the students could be guided through help options specifcally. Also the schema disclosed by the task format was partially adapted directly in the course of the further processing of the exercise sheet.
The more exercises the students have completed, the more the modeling skills were better performed and the schema was recognized and adapted to the following exercises. 80% of the probands calculated with all steps from the modeling cycle and solve the problems in sequence with less help (less hints were needed to achieve the right solution). By opening the task, i.e. reducing the taskstructure, they transfered their modeling knowledge and were better prepared to solve the problems and they know what problems they have and how to solve them.
A paper-pencil test in the winter semester 19/20 with 26 students has taken place. The test was structured in four scaffolded exercises and two open formed exercises. The schema which has to be used by solving the problem was the same in all exercises. The difficulty level increases step by step. Results showed that in some cases the structure of the scaffolded tasks was automatically applied to the open-format tasks while working on exercises with the same difficulty level. The more complex the exercise got, the more difficult was it for the students to see the schema and transfer it to the open formed tasks.

4 SUMMARY

To support the problem solving skills of the students in technical mechanics regarding to modelling an eLearning tool with scaffolded tasks and a specific feedback system will be used. With this composition it should be possible to recognize the modelling of a mechanical task and transfer it to open-format tasks and tasks of other context. Furthermore the individual learning process is focused by parameterized tasks and individual prompts.

The tasks and test instruments are currently being developed. For the selection and construction of the tasks, actually used tasks will be classified into different categories (difficulty levels, type of context, etc.) in order to be able to control the difficulty of the tasks. Therefore difficulty levels are operationalized with the help of complexity levels to be defined.
The pilot study will be carried out in a mechanical engineering course in the winter semester 20/21. The main study will take place a year later.

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DEVELOPING A SELF-ASSESSMENT TOOL FOR ENGINEERING STUDENTS ENGAGED IN OPEN-ENDED PROJECTS WITH A HUMAN-CENTERED DESIGN APPROACH

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Keywords (4): *design, open-ended projects, learning companion, self-assessment*

ABSTRACT

The paper presents an ongoing research project aimed at providing engineering students with a self-assessment tool when working on open-ended projects with a human-centered design approach. Based on our existing framework, we develop a tool aimed at alleviating some of the challenges experienced by students and faculty when running such projects. For instance, we have noticed that students face difficulties in framing problems, evaluating solutions or developing prototyping strategies. From a faculty perspective, it is not always easy to identify which students struggle with different phases specific to projects with a design approach and thus to provide the best possible support to students at the right moment. The tool offers a set of questions to assess students' progression and provides guidance to help in case of difficulty. Faculty can thus better allocate their time by focusing on those experiencing difficulties and ensure that those unaware of difficulties remain "on track".

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1 RATIONALE AND PRELIMINARY RESEARCH

1.1 Rationale

In our experience, developing and running courses for open-ended projects with a human-centered design approach faces a number of structural challenges :

- Fit with the rigid and highly structured academic timeline, with a weekly structure and fixed assessment periods; for instance, not all teams progress at the same speed, or some teams undergo several iterations which can lead to teams being at different points of the process at a given time; this raises questions of facilitation (e.g., nature and frequency) and, more generally, of the logic of progression
- Alignment with an academic mission which tends to emphasize learning over result; this raises questions of assessment (e.g., tension between mastering the process and reaching an acceptable result)

These challenges echo findings from the literature on design thinking education in engineering schools. Dym & al. [3] have argued that teaching divergent inquiry in design thinking is neither recognized clearly nor performed well in engineering curricula. More precisely, they posit that “the real challenge is not the adoption of the principles of divergent-convergent inquiry; rather, it is the integration of divergent-convergent inquiry into the existing engineering curricula”.

On the same topic, Bennetts, Cheeley, Caldwell, & Green [1] find that students' ability in divergent thinking remains stagnant throughout their engineering degree. More recently, Coleman & al. [2] find that “the perceived design thinking ability of senior engineering students is significantly less than that of first-year students interested in engineering” and call for development of feedback seeking and experimentalism skills.

Retna [10] points to two other important issues: engineering students’ inexperience in real life problems and research, and class size facilitation. While highlighting the value of design tools, Mosely & al. [9] point to issues of problem definition (e.g., difficulties in framing and reframing the project brief) and the experimentation and failure process during problem-solving. They also address the question of facilitators and their ability to provide guidance and feedback on the design process for non-design students.

In short, while developing competences to work on open-ended projects is broadly recognized as an important learning objective, it meets with challenges for both students and faculty members.

In light of the above, we wanted to capture in more detail the diversity of difficulties faced by engineering students at different moments of their project and propose a tool allowing them to assess their progression and, if necessary, help them overcome the difficulties in the form of questions.

1.2 Preliminary Research

We conducted a survey in 3 different EPFL courses consisting of semester-long open-ended team projects with a human-centered design approach. Teams were introduced to the way we, in our methodology, differentiate 3 main phases in open-ended projects (as described in the "Framework" part), and were asked to list the difficulties encountered in the different phases of the process. The survey was conducted at the end of the process, allowing for reflexive feedback. It targeted the phases of the process experienced by the students in their respective course. Table 1 provides the results of this survey, later referred to as "test 1".

Table 1. Difficulties faced by students in design-driven open-ended projects

Verified		Discovered	
RESEARCH : Explore (n=6)			
We didn't know how to proceed	50%	The topic was not framed well	16%
We didn't know which field(s) to investigate	50%	We were divided on which topic to explore	16%
…	< 50%		
RESEARCH : Define (n=6)			
We didn't know if our opportunity was relevant	66%	We didn't know if our opportunity was yet addressed	16%
We didn't know if we had enough data	50%	We didn't know how to formulate our opportunity	16%
...	< 50%		
IDEATION : Generate (n=15)			
We didn't know if our ideas were good or bad	60%	We put too many constraints on ourselves	21%
The constraints limited our ideas	53%	We struggled finding new ideas	13%
...	< 50%		
IDEATION : Select (n=15)			
We didn't know on which criteria we should base our choice	40%	We didn't know if our solution was realistic	27%
We had to mix 2 or more solutions	33%	Constraints forced us to choose a specific solution	13%
…	< 30%		
PROTOTYPING : Build (n=13)			
We didn't know how finished our prototype was supposed to be	70%	We encountered technical difficulties	23%
We didn't have the skills to build it	38%	We had internal team issues	23%
…	< 35%	…	< 10%
PROTOTYPING : Test (n=11)			
We had no testing strategy	27%	…	< 10%
We didn't know how to run tests	27%		
...	< 20%		

Source: compiled by authors

All of the pre-identified difficulties were confirmed. New ones were also identified, highlighting how different the experience can be when confronted with the same process.

Some of the difficulties confirm earlier literature findings, such as the importance of setting the right amount of constraints [4], echoing the tension between the need for structure and the freedom required by open-ended projects. Most difficulties faced by the students, however, fall under a “how-to” umbrella, illustrating a lack of methodological know-how from students when exposed to such processes, particularly in the first steps of the process (i.e, the Research and Ideation phases). This echoes our experience: the need for methodological mentoring becomes decreasingly important as the students evolve through the different phases. While crucial in the phases which engineering students are the least familiar with, it is less important in the “hands-on” phases (i.e., Prototyping). Also, the more students take ownership of the process, the less mentoring is needed.

Some of the difficulties highlighted also confirm what is identified in the litterature as the “exit dilemma” [7]: being uncomfortable when relying on soft skills, dealing with ambiguity [5] and solving real-life problems [10]. It remains hard for students to measure what is the right amount of try, fail, and the quality of their outcomes in regard of the tension between the exploratory nature of their projects and the academic timeline.

The existing literature, coupled with our experience and survey findings, comforted us in the need to develop a tool aimed at alleviating some of these issues.

2 PRESENTATION OF THE FRAMEWORK AND THE TOOL

2.1 The Framework

We conceptualized our self-assessment tool on the basis of a framework that we developed and refined over the years through a number of courses conducted at EPFL. The framework takes its inspiration from a number of approaches developed since the mid 90’s (e.g., British Council, IDEO). At the core of these approaches, one can usually find such concepts as convergence and divergence, iteration and human-centered design.

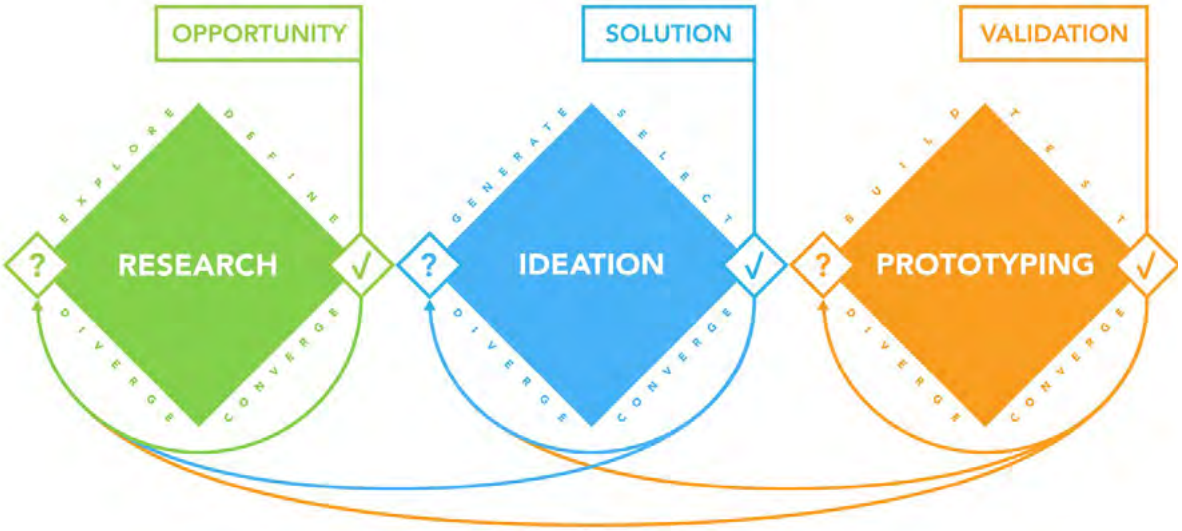

Fig. 1. RIP Framework

Our framework attempts to cater as much as possible to an academic context. For instance, emphasis is placed on process modularity to take into account the diversity of course formats and learning outcomes. In certain cases, a project brief is already defined (e.g., given by an industrial partner). In other cases, there is no project brief and students have to start from a white sheet of paper. At EPFL, many open-ended courses tend to start either at the Ideation phase, or at the Prototyping phase. In other words, the brief is already given, in a more or less framed state, but very little if no time is usually dedicated to research and the proper “building” of this brief with students. At times, faculty wants to emphasize process (whatever the result); at times, it prefers to ensure a certain quality in the result (e.g., in the case of service design or field intervention) or encourage technical innovation over market demand. Moreover, some projects run over a week (e.g., block module) while others can last several semesters (e.g. a minor or a competition).

2.2 The Self-Assessment Tool

The proposed self assessment tool is designed as a digital mediator whose goal is to unload the weight of automatisable interactions off the shoulders of the facilitator by providing students with essential support during open-ended projects with a human-centered design approach. It should therefore allow for better and more targeted interactions with the students requiring help.

The tool was developed with a number of different pedagogical scenarios in mind :

- Semester or multi-semester course: a more traditional approach fitting into the regular academic calendar
- Stand-alone project: students are increasingly participating in “practical” projects (either credited or non-credited, supervised or unsupervised)

- Design sprints: as schools develop new teaching formats, some favor block formats where students focus their energy on a single project for a limited amount of time

In its current implementation state, the tool works as follows: in a dedicated interface, the facilitator first sets up its course, that students can then enroll in. He sets which phase among Research, Ideation and Prototyping will be covered by the project (at least one, and if only 2, they must be consecutive).

The student then opens the self-assessment tool and enrolls in the corresponding course. Building on litterature's statement [6] that formulating questions is a best practice in design-driven open-ended teaching, the tool then offers the student a sequence of questionnaires, each corresponding to one of the phases covered by the course. When the student wants to assess progress over a specific phase, he takes the corresponding questionnaire. One cannot bypass a phase as a phase needs to be validated before proceeding to the next one.

Each phase's questionnaire is designed as a series of 3 to 4 questions targeting key-elements of the phase, inviting the student to reflect on his progress. A set of 8 potential answers is proposed, covering situations the student might identify with.

After the questionnaire, a comprehensive diagnosis highlights the results of the student in each key aspect of the phase and proposes tailored advices and reflexive questions, inviting the student to evaluate the quality of his work. Also, he's provided with a reality check on whether he can proceed to the next phase or not on the basis of the results. It prevents students from moving on to the next phase too quickly - which is a natural tendency in such contexts [5].

In open-ended projects, constraints, success criteria, and failure should be clearly outlined [8], something even truer as the mediation becomes digital. Therefore, questions, answers and feedback are designed to be comprehensive, yet straightforward.

This self-assessment should allow the student to reflect on his work. At the same time, the backend of the tool allows the facilitator to oversee the progression of the students and identify pain points: this should allow to better tailor what resources to provide & time to allocate for specific "debugging" with teams in need.

3 EARLY VALIDATION PROCESS AND FINDINGS

3.1 Early Validation Process

As a first step, the validation process of the self-assessment tool targeted the understandability, the relevance and the usefulness of its components - namely questions, proposed answers, diagnosis and advice. While still technically in a beta version, we recently reached a point where it became possible to test some of its key aspects.

We took the case of a social innovation program we run in India to present the participants with this early version of the tool and gather feedback. The setup is one of the typical use cases of our tool: 10 students were engaged in a 2-week design research process covering Research, Ideation and Prototyping. Students are split in 3 teams, each working on a different design brief. In addition, students come from 3 different backgrounds: engineering (various fields), business and design. Each team is composed of students of at least 2 different backgrounds.

We first introduced the students to our framework, then to the beta version of the tool. Both the work-in-progress nature of the tool and the goal of the test was explained to the students. Individually, they were asked to use the tool one time per phase of the process. Each time, they were then asked to provide anonymous feedback on the segment of the tool they just used.

Table 2 provides this feedback (hereinafter referred to as “test 2”).

Table 2. Self-assessment tool testing feedback

RESEARCH (n=7)				
QUESTIONS	Understandability	Relevancy	Understandability	Variety
Topic	71,4%	100%	85,7%	14,3%
Exploration	85,7%	85,7%	100%	42,9%
Interpretation	100%	100%	100%	57,1
Problem	100%	100%	85,7%	71,4%
DIAG. & AD.	Understandability	Usefulness	Understandability	Usefulness
	100%	85,7%	100%	85,7%
IDEATION (n=3)				
QUESTIONS	Understandability	Relevancy	Understandability	Variety
Ideas	100%	100%	100%	100%
Sorting	100%	100%	100%	66,7%
Solution	100%	100%	100%	100%
DIAG. & AD.	Understandability	Usefulness	Understandability	Usefulness
	100%	100%	100%	100%
PROTOTYPING (n=0)				
QUESTIONS	Understandability	Relevancy	Understandability	Variety
Criteria	-	-	-	-
Prototype	-	-	-	-
Testing	-	-	-	-
Validation	-	-	-	-
DIAG. & AD.	Understandability	Usefulness	Understandability	Usefulness
	-	-	-	-

Source: compiled by authors

First, we can see that student feedback participation dramatically decreased over time. Following in person discussions with students, the decrease can be attributed to 2 reasons:

- The logic, structure and wording of the tool barely varies along the 3 phases. Students therefore considered that their feedback on any of the phases wouldn't change much.
- As the process unfolded, pressure in delivering the final outcomes of the program increased and didn't allow time for reflexive feedback on the tool.

Based on the above results, and keeping in mind the small sample, one can see that the wording of the tool is by-and-large understandable. Given the goal of the tool, the questions appear mostly relevant and the diagnosis and advice delivered by the tool feel mostly useful. However, one can see that the proposed answers don't come across as varied enough.

These results were confirmed by direct feedback: students that answered “no” to any of the above questions were asked to explain why, and to provide suggestions for improvement. Overall, the feedback fell into 3 main categories:

- Lack of diversity and details of the proposed answers: multiple comments pointed out that the proposed answers didn’t represent the spectrum of the different difficulties faced by students during the process, and therefore didn’t match their experience. In addition with the impossibility to provide further details or to add nuance, students provide the answer that they feel matches their experience the most, which is the “least bad”, and they can therefore feel a mismatch between the diagnosis provided and their experience. In particular, it was mentioned that the ratio of affirmative and negative answers should be more balanced. Suggestions were made to switch questions to answer to, to affirmations to relate to, and answers to a 1-10 scale.
- Interdependencies: one comment pointed out that the tool should count specific answers as red flags, and that the phase diagnosis shouldn’t be a simple average of the results of the questions: it shouldn’t be possible to consider a phase validated if something went wrong in the first steps. While this is the mechanic of the tool between the 3 main phases, this suggests to also implement it inside the phases.
- Lack of clarity: while the wording was considered clear, some comments pointed out the lack of clarity of the concepts underlying the tool. Specific vocabulary should be thoroughly explained in order to leave no ambiguity (e.g., by adding examples). Furthermore, comments pointed to the need of explaining the underlying framework.

3.2 Discussion of Findings

We identified 2 biases in test 2:

- As this program was coordinated by us, it was built following our framework. When students used the tool and provided feedback, they were therefore already familiar with the underlying concepts and the specific glossary we had introduced in the course. This leads to temper the feedback: as the tool is intended to be used across the institution, but not all design driven open-ended projects courses in the institution embrace our framework, this setting is unique.
- As the process was unfolding over the short program, time became scarcer and pressure grew. Students had more time and reflection to allocate to the testing and feedback of the tool in their project’s Research phase, and less so in the other phases. This is verified by comments such as “same as for the Research phase” in the Ideation and Prototyping phase, leading to consider the Ideation phase feedback as more trustworthy.

While literature [6] suggests that formulating questions is a best practice in open-ended teaching and results from our test confirm this statement, we observed that in

the case of multiple-choice questions, they should be linked with meaningful answers that match students' experience. If not, it can make it hard for students to answer, knowing that their answer will not match the nuance of their experience. Proposed answers should thus reflect this nuance in order for students to be able to truly answer the question. Students might otherwise feel like any of the resulting diagnosis is not trustworthy or applicable.

Surprisingly, we can see that the diagnosis and advice were mostly rated as understandable and useful. As we knew that the proposed answers to our questions were narrow and didn't allow for nuances, we designed the diagnosis and advice to be as comprehensive as possible. This might be a way to overcome the lack of granularity of the answers, but won't change the students potential mistrust in diagnosis resulting from an answer not truly reflecting their experience, which is likely to vary a lot, as highlighted by the great variety of the difficulties faced by students reported in test 1.

4 FUTURE STEPS

The deployment of the first version of the self-assessment tool throughout the institution is envisaged over the coming semester, and upcoming developments shall build on the 3 main aspects of the findings. While the use of the framework "in presence" has shown positive results in terms of structuring our courses and guiding students through the different phases, one will need to verify whether the self-assessment tool "at a distance" manages similar results. For instance, it will be important to test whether the generic advice provided by the tool can replace more targeted advice provided by faculty. One will also need to ensure that the students answer "honestly" the questions and act upon the advice. More broadly, one will need to find the right rhythm for the coverage of theoretical aspects in each phase, the use of the self-assessment tool and facilitation about the project so that the students adopt the tool as an integral part of their learning journey.

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ENGINEERS FOR THE FUTURE: LESSONS LEARNED FROM THE IMPLEMENTATION OF A CURRICULUM REFORM OF TU/e BACHELOR COLLEGE

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ABSTRACT

With the purpose of educating *Engineers for the Future,* Eindhoven University of Technology launched the 'Bachelor College' (BC), a major university-wide framework to reform the curriculum structure, design and delivery of its bachelor programs. The ambition was to increase the student intake, broaden diversity in graduate engineering profiles, reduce drop-out rates, improve academic success, put students in charge of their own studies and educate '*future proof*' engineering graduates. The BC-framework has been extensively evaluated to assess the design, quality and impact of the reform. Results indicate lecturers' and students' satisfaction with the framework, particularly the *Major (i.e. main disciplinary components in each bachelor study program)* and *electives*. The new elements of the BC, i.e. *Use Society and Entrepreneurship (USE), Professional Skills* and *Coaching,* need further optimization. In this paper we report on the process of implementing the BC reform. Critical successful factors, such as engaging all stakeholders in the process, making a thorough system analysis of the consequences of the reform and stimulating cross-departmental cooperation and exchange of (educational) expertise are addressed.

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1. INTRODUCTION

In September 2012 Eindhoven University of Technology (TU/e) launched a systemic reform of the curriculum structure, design and delivery of all bachelor programs.Inspired by cutting edge engineering educational reforms in universities worldwide [1], the TU/e initiated a major transformation aiming at upgrading the content and structure of the educational programs to educate the new generation of engineers. This educational reform also embraced educational principles such as active learning and the introduction of formative assessment. The aim of this paper is to describe the process leading towards this reform as well as the outcomes of the implementation. The organizational approach can be found in annex 1. In this paper we will also share the main lessons learned from these two perspectives.

1.1 General overview of educational reforms worldwide

In the past decades the engineering education sector entered a phase of fundamental change [2]. The focus of the rapid transformation to educate engineers for the future centered around a need to create connections with industry, to introduce an interdisciplinary curriculum and technologies in the engineering diciplines, with emphasis on hands-on education, working in multidisciplinary teams and skills development [3-4]. Universities such as Massachussets Institute of Technology (MIT), Olin College, University of Aalborg, Delft University of Technology, and Standford University, were considered the 'current top five leaders' in engineering education [1] as they managed to lead educational reforms to include multidisciplinary components, partnerships with industry and a curriculum that stimulates creativity, innovation and experiential learning.

To mention some experiences at other universities that served to inspire the educational reform at the TU/e, for instance, the Olin College reform embraced several interesting insights in the set-up of the programs. The first semester classes provide hands-on experiences in different disciplines of engineering and throughout the curriculum students work on real-life challenging projects. Also, the first year courses comprise other disciplines such as arts, humanities, social sciences as well as entrepreneurship rather than only engineering domains. Similarly, at MIT, in the New Engineering Education Transformation (NEET) Program, students are engaged in solving challenges of the 21st century valuing multidisciplinary, collaborative, project-based learning. Within the NEET framework, students earn a degree in a major while they also get the opportunity to earn a NEET certificate in one of the five cross-departmental pathways or "threads", i.e. Advanced Materials Machines, Autonomous Machines, Digital Cities, Living Machines and Renewable Energy Machines. Incited by these experiences, the TU/e embarked in a similar reform to educate the T-shape of engineers by integrating systems thinking in core activities and across disciplines, by providing Use, Society and Entrepreneurship (USE) themes in all programs, and by enhancing professional skills, among other elements.

1.2 Drivers for curriculum reform

In 2011 bachelor student intake numbers at TU/e were very low compared to other Dutch universities and had even dropped below a sustainable level for several programs. Furthermore, the programs mostly attracted students who were intrinsically motivated for technology and hardly any students with a societal or career-related type of motivation for technology. Moreover, the average drop-out rate of students for these programs at the time was about 33%, which worsened this situation. Those students who decided to stay needed on average 5 years to finish their three-year bachelor programs, which put the sustainability of the university at risk.

1.3 Educating *'Engineers for the Future'*

Due to changes in the demands for engineers in the labour market [5], TU/e noted, as did other institutes of engineering education, that the nature of engineering is changing rapidly [6]. 'The' (standard) engineer no longer exists. Instead, a wide diversity of engineers is needed to make significant and innovative contributions to society throughout their careers. Society is in need of young professionals with a solid scientific foundation, excellent professional skills, who are able to address interdisciplinary problems and challenges and to cooperate with colleages from various disciplinary backgrounds, to respond flexibly to the fast growing body of knowledge and rapid changes in industry as well as society, to help shape the future in a responsible way, and with a strong awareness of their own strengths and ambitions.

In order to respond to this shifting nature of engineering and to address the student intake and academic success challenges, TU/e embarked on an institution-wide, systemic educational reform of its bachelor programs [7-8].

2. EVALUATING THE IMPLEMENTATION OF TU/e BACHELOR COLLEGE

2.1 Aligning the quality assurance system

The reform of the bachelor programs required a quality assurance system that would be aligned with this reform. At several levels, quality assurance elements were either adjusted, redesigned or added. Student surveys at the level of course and curriculum evaluation were redesigned and standardized, one-on-one review meetings between the Dean of Bachelor College and Program Directors were initiated, and measures were taken to improve annual education reporting by the departments. And finally, short feedback loops were initiated to make improvements on the fly, for example by creating and having regular meetings with the Student Monitor Group, in which every bachelor program is represented by one student. The overall aim was to close the quality assurance cycles at program and course levels.

2.2 Scope of the two-impact evaluation studies into TU/e Bachelor College

At the launch of Bachelor College it was agreed to evaluate the framework after completing the first three-year cycle of the reformed bachelor programs. This evaluation was conducted by an external expert in 2015 [9]. A joint agreement was also made to evaluate the framework as a whole a second time, in 2019, and based

on that evaluation, either redefine the framework as a whole or formulate an adapted framework for a new cycle.

Though the set-up for both impact evaluation studies of TU/e Bachelor College was similar, their goals were partly different, due to the alignment with the timing of the studies. The first evaluation (covering the 2012-2015 period) focused on the early impact and success of the reform with particular emphasis on three of the strategic aims: the increase in the size and broadening of the demographic of student intake at TU/e; improved student drop-out and study success rates; and, improved student flexibility and educational choice. It also centered around the evaluation of the design and delivery of TU/e Bachelor College to identify any operational challenges, risks and opportunities for improvement.

The second evaluation (2015-2019) broadened the scope by also including the other two strategic aims: creating 'future proof' engineering graduates and delivering a larger number as well as broader diversity of engineering graduates. To this end, four working groups were commissioned with investigating the following leading research questions: (1) Has TU/e achieved its five strategic goals with its redesigned bachelor programs?; (2) Do students recognise and appreciate the set-up of the Bachelor College in the education of future- proof engineers?; (3) How do Bachelor College graduates perform in the master?; (4) Do the engineers of the future have added value for their respective fields of work?.

2.3 Method of the two-impact evaluation studies into TU/e Bachelor College

As mentioned above, the two evaluation studies followed a similar method consisting of quantitative and qualitative research methods. In the first evaluation, an external expert conducted the whole evaluation study [9]. In the second evaluation, four TU/e working groups conducted the quantitative part of the research [10-11]. They extracted and analysed data from the TU/e BI platform (generates and shows education-related data) to investigate trends in student intake numbers, drop-out rates, study completion rates and academic performance of master students. Online surveys were used to explore student and teaching staff perceptions of and experience with the reformed bachelor education. An overview of the response rates for the various groups is provided in Table 1.

Table 1. Participants quantitative research first and second evaluation of BC

First evaluation (2012-2015)

Research method	**Target group**	**N=response**	**% of the total group**
Online surveys	Bachelor College students	N=838	46%
Online surveys	Pre-BC Students	N=499	29%
Online surveys	Lecturers	N=342	40%

Second evaluation (2018-2019)

Research method	Target group	N=response	% of the total group
Online surveys	Bachelor College students	N=1581	25%
Online surveys	Master students	N=378	16%
Online surveys	Lecturers	N=295	18%

The qualitative research part of both evaluations consisted of one-on-one interviews that were designed to explore the issues raised in the survey in more depth. In the first evaluation individuals were selected (n=44) with a range of backgrounds (senior university managers, change managers, lecturers, educational directors and students, as well as external observers of the reform). In the second evaluation the external expert conducted the interviews with bachelor students and graduates, and lecturers (n=16).

3. RESULTS

3.1 Outcomes of the first evaluation

The results of the first evaluation indicated a broadly positive impact and successful change. Most impressive were the results for the size and demograhic balance of the student intake already obtained in 2014 (aim 2, see section 2.2 above): a growth of 52% in student intake numbers and an increase in the proportion of female students from an average of 14% to 24%, in which the well-designed marketing and communication strategy played a crucial role. The impact of the reform on student drop-out and study success rates was also quite positive (aim 3, see section 2.2 above). Students' educational choices also showed good progress (aim 4, see section 2.2 above).

A number of challenges emerged from this evaluation as well. They were in line, however, with what might be expected for a change of this scale and ambition. In addition to the very positive feedback, staff and students for example raised their concerns about the contents, quality and delivery of the USE learning lines, the professional skills component and some of the engineering basics. In response to these concerns, several measures were taken. New requirements for the USE learning lines were developed with the aim of improving the rigor, strengthening the integration of engineering and social sciences and enhancing the match with students' interests and ambitions. For the professional skills, the framework was revised and an internal audit system was developed to help program directors redesign the integration of the professional skills within their Major. For the engineering basics a cross-departmental lecturer team was composed to review and redesign the set of courses as a whole.

Two interrelated issues in the Bachelor College's design and implementation were more fundamental: the coherence and integration of the Bachelor College curriculum components and the opportunities available to students to apply and integrate their knowledge. In the absence of an overall framework within which to contextualise what they are learning in courses such as the USE learning lines, many Bachelor

College students appeared to assign a low value to these experiences. As a result, learning and impact from these courses may have been limited. As part of the reform of the bachelor programs, the credit load attached to the Major was reduced from 150 to 95 ec. During this process many departments appeared to have reassigned project-work from the 'core' curriculum to the elective space, thus reducing the amount of knowledge application. In addition, courses outside the Majors attempting to deliver active learning experiences were doing so under very difficult circumstances such as large student numbers (all 1st-year students take the engineering basics courses at the same time). A result of this was that students appeared to have few opportunities to apply their knowledge to authentic engineering problems and engage with deeper modes of learning in their Major.

Despite these challenges, the foundations of Bachelor College's long-term success seemed to be in place: "*It represents an ambitious and groundbreaking approach to engineering education which is likely to offer a template for change to many universities and engineering schools across the world*."[9]. The committed support of the university senior management, the rapid successes already achieved and a well-designed communication and marketing strategy played a crucial role in this.

3.2 Outcomes of the second evaluation

The second evaluation of the Bachelor College [10] aimed to review (1) whether the TU/e had realized its strategic goals with the redesigned bachelor's program; (2) whether the students recognise and appreciate the set-up of the Bachelor College in the education of future- proof engineers; (3) the level of performance of the Bachelor College graduates in the master; and, finally, (4) the added value of the engineers of the future for their respective fields of work.

Results of the evaluation indicated that the reformed bachelor programs attract a larger and a more diverse student intake than was the case prior to the reform, including increases in the proportions of female students, international students and non-local students (See annex 2: Student intake overall 2002-2019; and, annex 3: relative growth and compared to other Dutch Technical Universities). In addition, drop-out rates have decreased while graduation rates have steadily improved. Success rates had already started to improve before the BC reform and, therefore, we cannot contribute this success to the educational reform exclusively. In this regard, students recognize that their education provides ample opportunities (i.e. elective space) to them to shape their own engineering profile, develop a breadth of experience outside of their own engineering disciplines as well as depth of knowledge in their chosen specialiazation field (See 4: Success rates: completion rates cohorts 2002-2015 (target: 70% graduates in 4 years).

From the student survey we observed that students are satisfied about how the Major and the electives are embedded in the overall structure of the bachelor curriculum. However, students' perceptions indicate that they recognize objectives of the USE learning lines to a limited extent only, especially with respect to the objectives 'making use of USE aspects in developing technologies' and 'having a clear notion of USE in relation to technology'. Interesting to see is that students recognized the importance of the professional skills, although the embedding of the professional skills in the curriculum still needs attention. Similar results emerged

regarding coaching. Although the importance of coaching is acknowleded, the implementation of coaching still requires attention.

Regarding the research question on the performance of Bachelor College graduates in the master, insufficient data was available to compare Bachelor College students to external influx or to pre-Bachelor College students. The same applies to the final research question. At the moment, we cannot confirm the added value of TU/e Bachelor College graduates for society as they have only recently started to enter the labor market.

4. LESSONS LEARNED FROM THE EDUCATIONAL REFORM PROCESS

Developing, implementing and evaluating the BC framework has led to several insights which may benefit not only TU/e but also other universities in future large-scale educational innovation. Below we will report about the lessons learned from different perspectives, i.e. the reform of the bachelor programs and the process of standardization.

4.1 The curriculum reform process as a whole

First of all, it is essential to determine a strategy for a curriculum reform process in advance. Within this context, TU/e being a small organization has the advantage of offering flexibility and short communication lines. In this process, cooperation with all departments is crucial to take large steps. In order to implement such a large change, sufficient capacity and a clear mandate and responsibility of the bodies in charge of such an operation at the departments are required.

The departments were in the lead to implement the framework in their respective Majors. Experience has taught that strict and uniform regulations do not work with educational processes as flexibilization and adaptation to the various departmental cultures and disciplines remain relevant factors for success. An advantage of the TU/e approach to the curriculum reform was that it made it possible for the departments to shape their program within the framework and at the same time keep their own character and culture.

The degree of implementation differed therefore among departments. Several different factors appear to have played a role in this. First of all, the differences that already existed prior to BC were still visible after implementing the reform in some areas, such as the degree of student-activating education. Secondly, specific ways in which the departments organized the educational reform also contributed to differences in how the framework was implemented. Among these differences are the degree to which Program Directors were enabled to conduct the curriculum reform not only from a content point of view but also from an educational perspective, allowing substantial support to empower lecturers to introduce changes at course level as well. As a consequence, a large organizational change of the support staff and services took place in the years after the start of BC. The purpose was to harmonize and standardize the processes supporting education in order to make sure that the right expertise was available in the right place. Standardization and harmonization of educational reform processes must be, therefore, in balance.

Another rationale behind the implementation of the curriculum reform was to give sufficient freedom to the departments to introduce the BC framework in each bachelor program. This was done under the assumption that it would enable the departments -to learn from each other. This peer-learning did take place to a certain degree, but dissemination of best practices among the departments was more limited than anticipated. A good start was made by organizing education meetings, but these gradually disappeared over time. The workshops that were meant to replace them, took shape only to a limited degree. In the later years and in order to give impulse to the TU/e educational strategy and Vision 2030, funds were also made available for educational innovations. The implementation of this strategy was translated in programs such as Challenge-based learning, BOOST! (IT in education), Teacher and Teaching Assistants, within the context of the Ministry of Education Quality Agreements. Also Innovation funding of the Centre for Engineering Education (CEE) was made available to support these initiatives. Through these programs, the teaching staff is able to submit innovation projects under the lead of the Program Directors to carry out innovative initiatives in light of quality of education. These funds have enabled and stimulated teaching staff to redesign their education. In order to disseminate these initiatives, presentations of innovations are organized within the departments and at the TU/e education day. However, cross-departmental learning from these projects can be strengthened.

4.2 Reform of the curriculum components (i.e. basic courses, Major, electives, USE learning lines, professional skills)

With regard to the curriculum reform of the Major (i.e. the disciplinary components of the bachelor curriculum in each study program), strong educational leadership is needed in order to have a clear vision and avoid the inference of other university politically-oriented processes. A key factor is the empowerment of the lecturers to define and elaborate, on the basis of the aims of the study program, the core of the Major and the associated learning objectives (without losing the relationship with research). There must be sufficient support within the teams of lecturers, but also willingness and openness to develop the new courses.

The TU/e BC framework combining the preparation of engineers in a unique discipline (i.e. Major curriculum), the broad preparation that the basic courses provide, together with the electives, professional skills and USE learning lines pave the way to shape the new generation of T or π-shaped engineers who can respond to the challenges of society and the labour market.

4.3 Guidelines to improve study progress

Guidelines were developed in working groups consisting of many different stakeholders from all departments. Subsequently, the agreements made were communicated in various ways: by means of presentations on education days, captured in a Bachelor College framework, education and examination regulations, etc. To guarantee commitment in the implementation of an educational and curriculum reform, communication is essential. Investing in explaining the why and how as part of the preparation as well as implementation process are essential elements of all educational reforms.

5. CONCLUSIONS AND PERSPECTIVES FOR ENGINEERING EDUCATION

The evaluations of the Bachelor College have shown that the framework is a suitable and sustainable structure to shape bachelor programs and curriculum that educate the *Engineers for the Future.* This framework includes characteristics that enable the graduates to meet the challenges of the future worldwide. According to this vision, the TU/e contribution to society are engineers characterized by a T- or π-shaped profile, who have in-depth knowledge and expertise with cross-disciplinary insights, approaches and the skills to address real-world challenges; are able to collaboratively work in multidisciplinary teams; and provide solutions from a systems-thinking and creative thinking perspective.

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ANNEXES

Annex 1.

1.1 The organizational approach towards implementing the curriculum reform

The journey to the curriculum reform was started late 2010 by establishing a dedicated 'Redesign Bachelor Curriculum' Taskforce [5]. This taskforce analyzed the drivers for the educational changes and created a vision for future bachelor education at TU/e [6]. They also proposed possible future directions to address issues such as the diminishing student intake and relatively low study success rates [5]. Based on the final report and recommendations of the taskforce, TU/e's Executive Board decided to fundamentally reform TU/e's bachelor education and to unite all bachelor programs in a single 'TU/e Bachelor College'.

The main aims of this reform were to:

1. Create 'future-proof' engineering graduates who are able to operate effectively and professionally across borders and disciplines and are equipped to tackle the complex challenges of the 21st century.
2. Increase the student intake numbers and broaden the appeal of TU/e to new groups of prospective students (female, international and other 'beta-mentality types': not only students with an intrinsic motivation for technology but also students with a societal or career-related motivation for technology).
3. Reduce student drop-out rates and improve study success rates.
4. Provide education that is supportive, flexible and responsive to the individual needs and priorities of each TU/e student.
5. Deliver a larger number as well as greater diversity of engineering graduates

In order to prepare the implementation of the curriculum reform, the BC Dean was appointed as Program Manager to lead this process supported by a Program Management Team (PMT). Various projects were defined to accomplished the envisioned aims of the reform, which were conducted by different stakeholders distributed across working groups, i.e. program directors, policy advisors, teacher support staff and students.

The vision and the advice of the working groups together helped shape the Bachelor College framework, and the organizational systems and structures that made it possible to implement the framework. The vision was further developed into and described in *'Engineers for the future. An essay on education at TU/e in 2030'* [7].

Core elements of this vision include active student learning as the main driver for innovation of education, small-scale education, close student-student and student-lecturer interaction, diversity in student population and a focus on multidisciplinarity.

The process of implementing BC can be characterized as relatively quick. About one year and a half after the establishment of the original taskforce, the reformed bachelor programs were launched. Once the framework was established, the Dean of TU/e Bachelor College, supported by the Project Management Team, guided and monitored the implementation. Departments were given the lead in how to implement the framework in their respective bachelor program(s).

1.2 Systemic educational reform

TU/e Bachelor College launched an institution-wide framework that reformed the curriculum structure, design and delivery of all bachelor programs.

The curriculum of all bachelor programs was structured in the same way, consisting of the following elements (also see Figure 1): engineering basics (25 ec), a disciplinary Major (95 ec, including a Bachelor End Project of 10 ec and professional or '21st century' skills), a User-Society-Enterprise (USE) learning line (15 ec, restricted electives), and a substantial free elective space (45 ec).

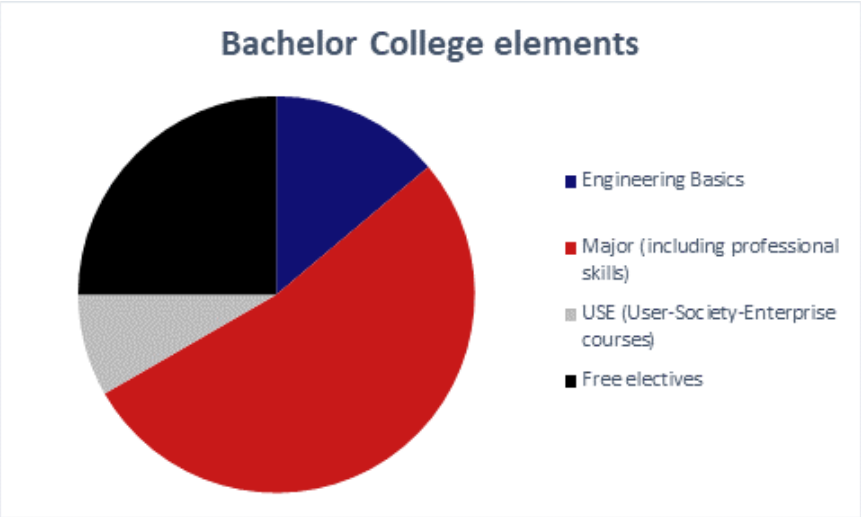

Figure 1 Bachelor College curriculum elements

In addition, all courses got a fixed size of five European credits (ec) and were programmed in a ten-week schedule, with only three courses running in parallel and a reduced number of contact hours to enable independent study. To enable these changes, fixed timeslots during the weeks were used to schedule all courses. Finally, several measures were taken to enhance study success rates such as introducing interim testing and reducing the number of resits [8].

All these standardized structural components were intended to create optimal flexibilization for students in shaping their own program and choosing their electives from the range offered by their own as well as other departments. This set-up of the free elective space served various kinds of students: students who aimed for depth in their chosen discipline as well as students who wanted to pursue their individual

interests and ambitions. Personalized coaching was introduced to support students in investigating their ambitions and interests, and making study-related choices accordingly. All these components addressed to the rationale to conduct the curriculum reform.

The university's marketing and recruitment strategy was fundamentally changed as well. A *'Let engineering make your dream come true'* campaign was launched and two new bachelor programs were designed to broaden the appeal of TU/e to new groups of prospective students. And finally, a new *'Study Choice Check'* to determine how well a study program suits the interest of the student, was developed to reduce drop-out rates.

Annex 2. Student intake overall 2002-2019

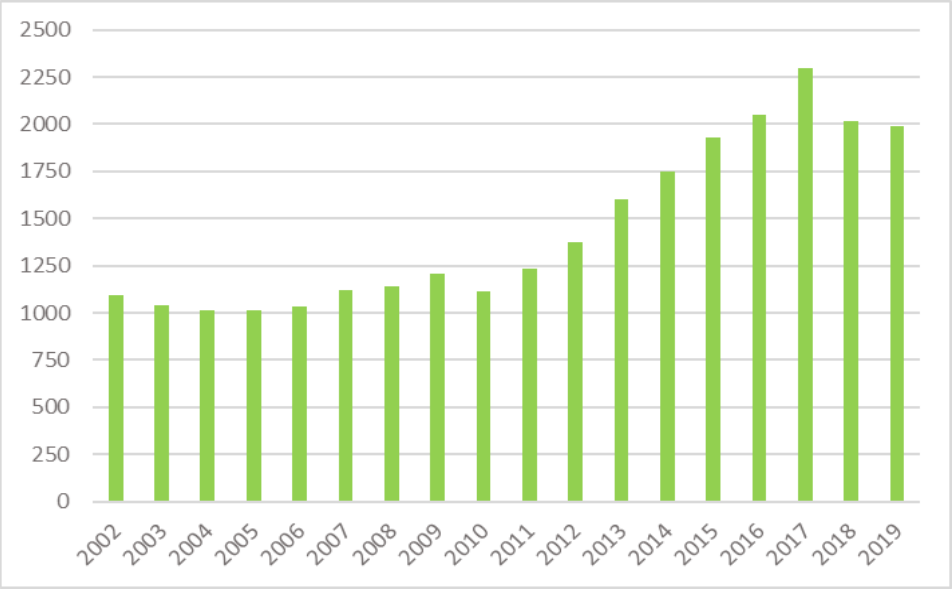

Figure 1. Absolute size of BSc student intake at TU/e since 2002 (source: TU/e BI Portal, BSc intake first-year institution 1 October)

Annex 3. Relative growth and compared to other Dutch Technical Universities

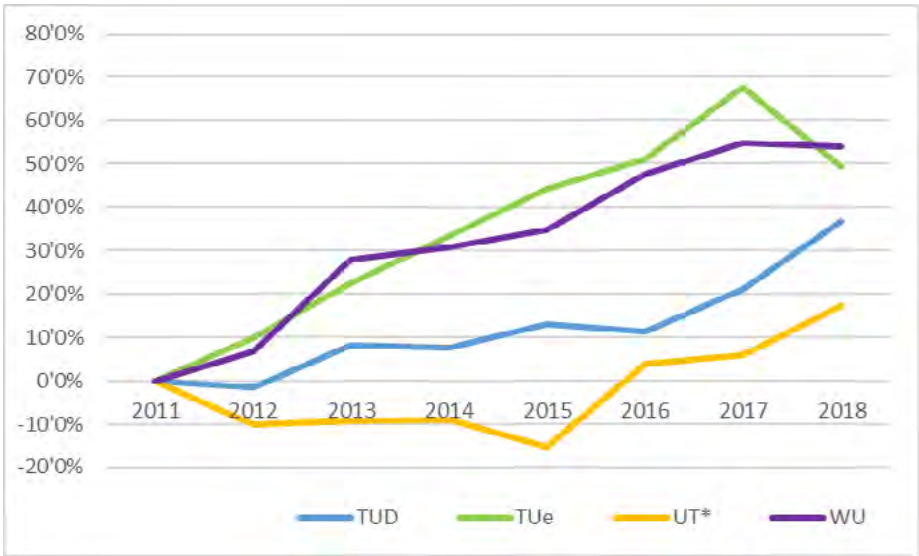

*Figure 2. Growth percentages BSc student intake at 4TU since 2011[2] (*includes intake for non-technology programs; Source: VSNU/DUO Intake first-year university students, main enrolments 1 October). Legend: TUD- Delft University of Techology; TU/e – Eindhoven University of Technology; UT- University of Twente; WU- Wageningen University.*

Annex 4. Success rates: completion rates cohorts 2002-2015 (target: 70% graduates in 4 years)

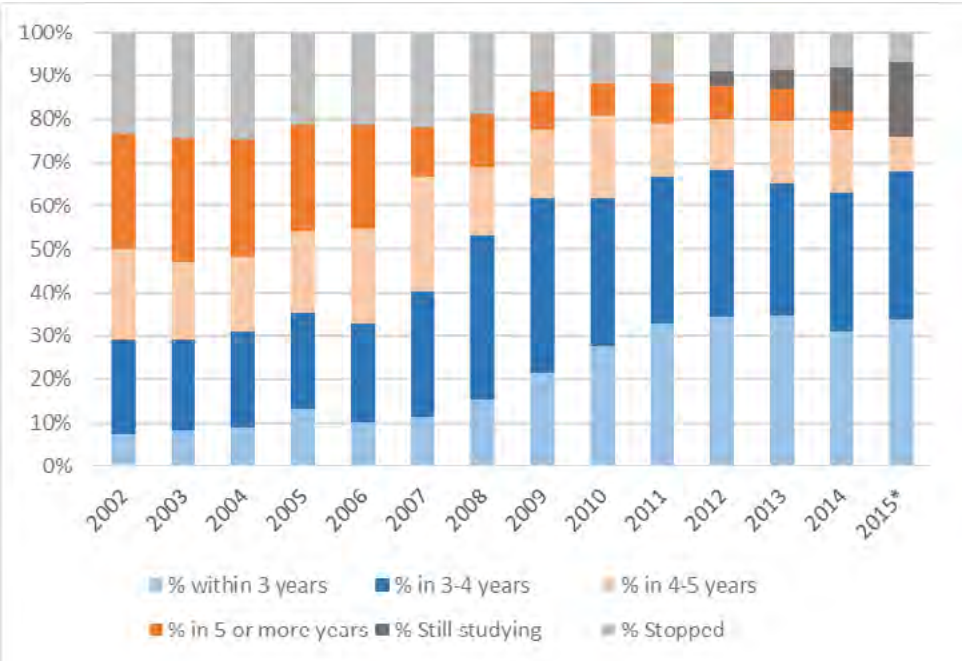

*Figure 3. Completion rates for BSc cohorts 2002 – 2015 (*data for cohort 2015 not yet complete[3]; source: TU/e BI Portal, Completion rates BSc students).*

[2] In order to determine growth percentages since 2011, this percentage was set to zero for 2011.
[3] For cohort 2014 data for 'diploma in 5 years or more' is lacking and for cohort 2015 data is lacking for 'diploma in 4-5 years' and 'diploma in 5 years or more'. This means that the grey part indicating the percentage of 'no diploma' will get smaller once data is available.

HOW AI IN ENGINEERING EDUCATION CAN HELP TO FOSTER DATA LITERACY AND MOTIVATION

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Conference Key Areas: *Challenge based education, Niche & Novel*
Keywords: *Engineering Education, Artificial Intelligence, Data Literacy, Motivation*

ABSTRACT

In the course of the megatrend digitalization, artificial intelligence has recently been receiving a new wave of attention. Within the production environments of the future, engineers and skilled workers will be reliant on information gathered from AI-based assistance systems while developing data-based solutions for complex issues of work. In this respect, integration of recent advances in AI and natural language processing could be of particular importance for engineering education. In respect to the design of engineering curricula, questions arise on how the existing body of knowledge can be linked to the topic of AI and beyond that integrate aspects of e.g. data literacy and motivation. The paper at hand focuses on providing reasons for integrating learning opportunities which deal with AI in engineering education. Therefore, the results of a questionnaire, carried out in the course of a research-oriented seminar, asking prospective technology teachers about their attitudes towards the use of AI in education will be discussed. Furthermore, guidance concerning the design and the integration of peer-to-peer AI workshops, in an interdisciplinary makerspace focusing on engineering education, will be presented. In the course of these learning activities, both future engineers and prospective technology teachers were confronted with reflective tasks in the context of the use of AI-based technology. The synthesis of the observations made, lead to a modular concept proposal to be discussed in this paper. Ultimately, the findings presented here, are perceptions from multiple projects, which will be merged within the framework of a more comprehensive project in the future.

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1 INTRODUCTION

The last few years have seen a renewed interest in artificial intelligence (AI). Here, strategy papers and funding lines focus on the integration of findings from AI research and encourage the development of AI-based applications across all economic sectors [1]. Especially against the background of the recent findings in the AI research fields of Deep Learning and Natural Language Processing (NLP), a technological answer to the qualificational challenges of industry 4.0 by multimodal human-machine interfaces has become increasingly feasible [2]. However, neither the current efforts concerning the integration of data-driven AI methods nor the interdisciplinary research field of AI itself are new [2, 3]. Furthermore, the general importance of data has been distinctive for manufacturing since the origin days of scientific management, and manufacturing already benefited from prior AI methods e.g. statistical process control. Despite this, the new quality and a low-threshold access to AI toolsets for manufacturing have been enabled lately by *Big Data* – i.e. the availability of data and computing power – and the so-called *Algorithm Wave* [4]. The increasing integration efforts on data-driven AI technologies in manufacturing are well documented [4, 5]. In a closer examination, NLP-based cognitive assistant systems should be emphasized as a field of special interest. Here, the recent progress concerning the recurrent neural networks (RNNs) – also see long short-term memory (LSTM) [9] – boosted the expectations about the added value of applications from the field of NLP. The current NLP hype reached its preliminary peak in late 2018 with reports of the human reading comprehension being outstripped by AI applications. And already today, these very same language models establish themselves in communication and expert systems, when start-ups (e.g. huggingface.co) emerge as industrial service providers to create value through data. Eventually, since a large share of the available data in our world is text-based and the importance of technical language in industry practice and engineering education (EE) can be described as a gold standard, a closer look at the field of NLP seems promising to integrate AI in EE [6]. All in all, it can be stated, that these technological phenomena of the digital change will affect working conditions in the future. However, changes in respect to the organization of work, the design of qualification paths, and the offered opportunities for competence development are a necessity for both, skilled workers and aspiring Engineers [7]. Therefore, learning to deal with the impacts of AI-based technology is vital to be able to act professional in the work environments of the future.

The paper at hand takes up the implications of the developments described above and offers a low threshold concept for integrating relevant AI topics in EE. Therefore, the data curation is based on a desk research, the students' and the tutors' feedback, and observations recorded during AI workshops in a makerspace environment. Against this background, research questions to be addressed in the paper at hand are:

(1) Which learning activities foster competences associated with the topic of AI and the development of meta-cognitive competences for data literacy and motivation?
(2) What are potential points of reference to integrate AI into the curriculum of EE?

2 OUTLINE OF THE TECHNOLOGICAL DEVELOPMENT LINES

The previously outlined aspects indicate that questions related to the design and the application-oriented integration of AI-based technologies are relevant for the further development of EE. This section describes the lines of development in AI, provides a work definition and underlines the importance of NLP for AI-based assistance in EE.

2.1 From electronic therapist to cognitive assistance

The transfer of human decision making to technical objects and its delimitation from human intelligence had already involved a variety of disciplines for some time when the Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI) in 1956 generated the starting point for the interdisciplinary field of AI research [8]. Up to the 1970s, the field of AI research was characterized by heuristic algorithms that were implemented manually using symbol-based programming languages. Following this period of rule-based AI, logic-oriented and functional programming languages became more and more accepted and the rise of statistic-based AI began, a time coined by the so-called expert systems [4]. At the beginning of the 1990s, the AI hype came to an end anew, once again due to overdrawn expectations towards these knowledge-based systems. The research work carried on at that time was a key enabler for many AI applications established today (e.g.: "history of backpropagation" in [9]). In a third phase learning systems based on deep learning algorithms dominated the field. In the upcoming fourth phase it is expected that cognitive systems will recognise the necessary contextual adaptations and use learning to update the knowledge base autonomously. The outlined developments of AI are shown schematically in figure 1.

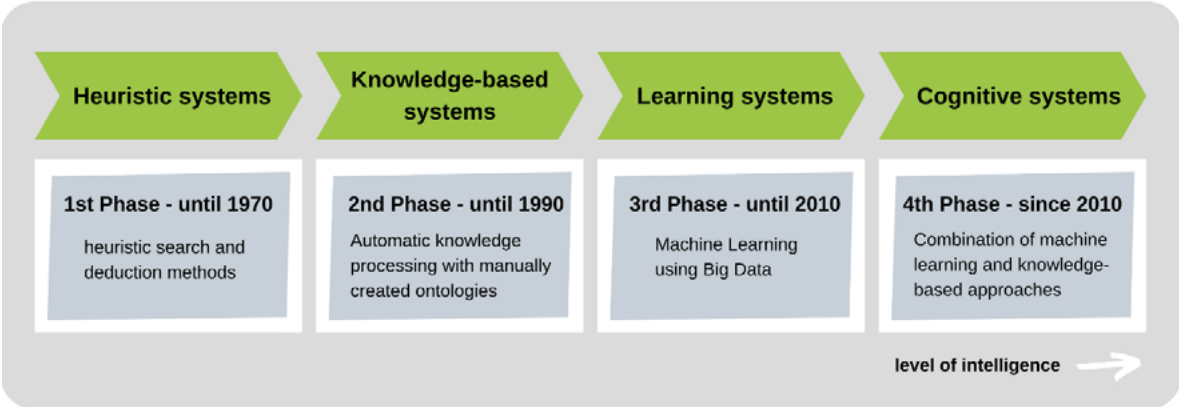

Figure 1: Previous phases of AI development [10]

As elaborated in the previous descriptions, the field of AI is in a state of evolution. Furthermore, the underlying notion of intelligence is, as an inherent part of human dispositions and despite the recent neuroscientific efforts, still not comprehensively defined at this point. Based on the perspectives discussed in [5], and in the course of the present article, AI is defined as a field of computer science, describing the efforts to reconstruct e.g. human decision making and problem-solving with the assistance of AI-based technologies (e.g. RNNs), to overcome human limitations (in regards to the the amount and the complexity of data) and thereby support mankind cognitively.

Prominent areas of AI application are quality control, optimized resource management, robotics, predictive analytics, knowledge management, intelligent sensor technology, intelligent automation, autonomous driving \ flying, and intelligent assistance systems. A commonly used structure for the areas of AI-related research is listed below[9]:

- Rational approaches (measurable or objective criteria exist):
  - Rules of complex processes \ action planning and optimization (e.g.: Route planning, self-orientation, navigation etc.)
  - Application of learning procedures \ machine learning (e.g.: statistical models, un-\ supervised \ reinforcement learning)
  - Recognition of image and image sequences via computer vision (e.g.: in the course of object, environment or affect recognition etc.)
- Behaviour-oriented approaches (unpredictability of requirements):
  - Representation of knowledge networks via semantic technologies (e.g.: Linked Open Data, Ontologies etc.)
  - Understanding natural language via natural language processing (e.g.: translations, question-answer systems, text-to-speech etc.)
  - Cognitive modelling (e.g.: simulation of emotion, decision making etc)
- Neuromorphic computing: i.e. hardware architectures imitating the human brain

In respect to the technology-related backgrounds presented, it may be stated that, both with regard to the basic statistical methodological knowledge and with regard to the relevance of current fields of application, AI proves to be a relevant topic for EE.

2.2 About the relevance of NLP-based assistance systems in EE

In a more detailed analysis of the relevant fields for the use of AI-based technologies the integration of cognitive assistance systems offers a promising perspective for EE [4, 5]. Here, NLP, in the sense of applied engineering and as a subfield of AI, combines findings from computer science, computational linguistics, and machine learning, provides the key bridge technology to enable human-machine collaboration. NLP describes the design of AI-based technology that enables machines to be able to read, process, generate and understand human languages [11]. includes language understanding and generation (NLP = NLU + NLG). Moreover, it is considered to be one of the most important application areas of artificial intelligence. It offers, in addition to low-threshold and practical access to the topic of language as a data source, several applications with references to the everyday reality of learners [12]. The broad field of applications, e.g. assistance and recommender systems, language translation, information retrieval and extraction, text analytics, predictive text, voice recognition, or the use of search engines underlines the comprehensive opportunities for competence development. For a more in-depth study of NLP, please refer to the works of [13, 14]. Furthermore, the Workshop Building Educational Applications (BEA) as the leading venue for NLP innovation in the context of educational applications organized by the Special Interest Group in Educational Applications (SIGEDU) should be noted [15]. Finally, e.g. Bhaduri validated the growing relevance of machine learning and NLP techniques especially for instruction and research context in the field of EE [6].

3 METHODOLOGY

The paper at hand is structured following the logic of triangulation, including a literature review, the discussion of the students' learner traces, and additional indications from formative feedback. Focusing the design of innovative learning venues, challenges such as the growing complexity [7], the individualisation of learning paths, and the documentation of digital traces, mapping these processes and the learning community are highly relevant to EE [17]. Recommendations, towards a modular course design presented here, are based on a design-based research approach (DBR), whereby this publication can be seen as a first test to the underlying hypothesis [16]. While these basic conditions are also taken up at the political programme level and may be understood as a claim rather than a challenge with concern to the design of teaching and learning, conditions for success or even recommendations for implementation are still lacking in context with the integration of AI in engineering education [18]. For a more comprehensive examination concerning the recent course of dealing with the integration of AI technology in education, please refer e.g. to the publication of Zawacki-Richter et al. [19].

The survey, which is presented in the following, used a questionnaire developed with prospective technology teachers in a course on research-orientation. The overall course design is also subject to a DBR approach focusing innovations of EE in context with the scholarship of teaching and learning, i.e. dealing with questions concerning autonomy, motivation and the impact of AI-based assistant systems [20]. The questionnaire was conducted as pen and paper format addressing multiple groups of students in teacher training in winter term 2019 / 2020. The students' hypothesis assumed a correlation between the assessment of AI technology and the attitude towards the use of AI in education (H1). Therefore, a first self-assessment on AI asked at which point the respondent would classify the use of a technology as AI in education. The participants were asked to mark their views with a cross at any position, while on the far-left side the scale starts with "Smartboards", and is limited with "Learning software with independent network features" on the right end (see fig. 2 – the scaling is intended to help to interpret the results and does not correspond to the original figure given in the course of the questionnaire). Also, data about the personal opinion on the use of AI in education has been collected by asking for a level of agreement concerning 10 statements on AI (scale: does agree = 4, does rather agree = 3, does rather not agree = 2, does not disagree = 1). Furthermore, the learners decided to differentiate between age and gender in order to be able to set priorities in the subsequent reflection reports, which represent their study assessment.

As mentioned above, the overall research design includes the collection of demands, attitudes and prior knowledge in the context of AI (in education) on the one hand and an iterative implementation and evaluation of different learning opportunities on the other hand. The data from the formative evaluation, the queries of prior knowledge, and the students' and the tutors' feedback regarding peer-to-peer workshops on AI were collected in two consecutive semesters (summer term 2019 and winter term 2019 / 2020) in a makerspace environment focusing on engineering education [21].

4 RESULTS: LEARNERS' REFLECTIONS ON THE USE OF AI

The following section introduces results of a questionnaire, the findings concerning the implementation of peer-to-peer workshops on AI and outlines the preliminary findings.

4.1 A students' survey asking their fellow students about the relevance of AI

All in all, 96 persons participated the questionnaire. After data cleansing data reports on a total of 95 surveys. 55 are female (% 23.4 years), 39 are male (% 24.1 years). 75 are enrolled in a MINT subject, 56 are in a Bachelors', and 37 in a Masters' degree.

Figure 2 illustrates the self-assessment item about technology use in education, which differs from the depiction in the survey i.e. with regard to the here inserted numbering. Findings show a mean value of 11.3 for women, which represents "speech or text recognition" and a slightly higher mean value for men (12.6), which represents "smart translation systems". Concerning the breakdown of answers, please refer to figure 3.

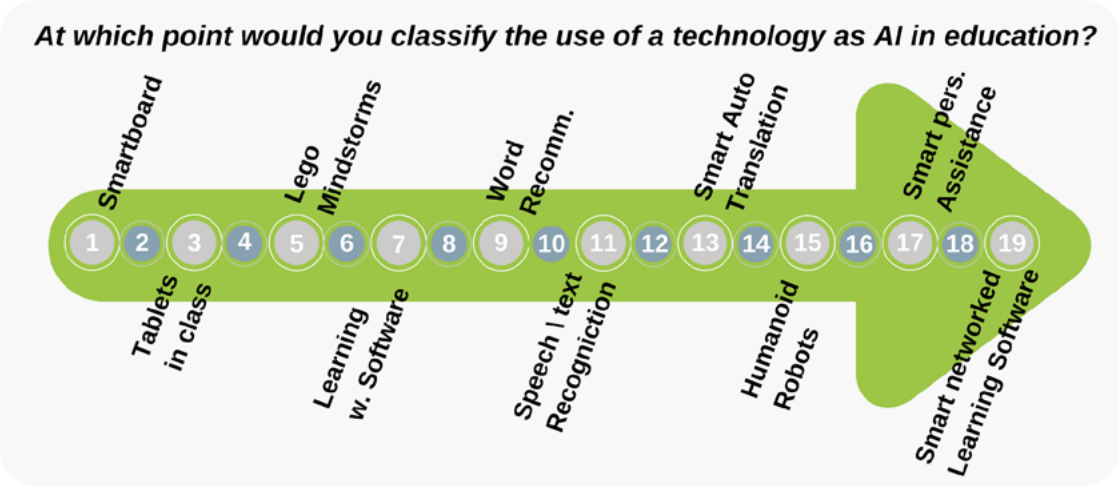

Figure 2: Answer scale self-assessment "Which technology level corresponds to AI in education?"

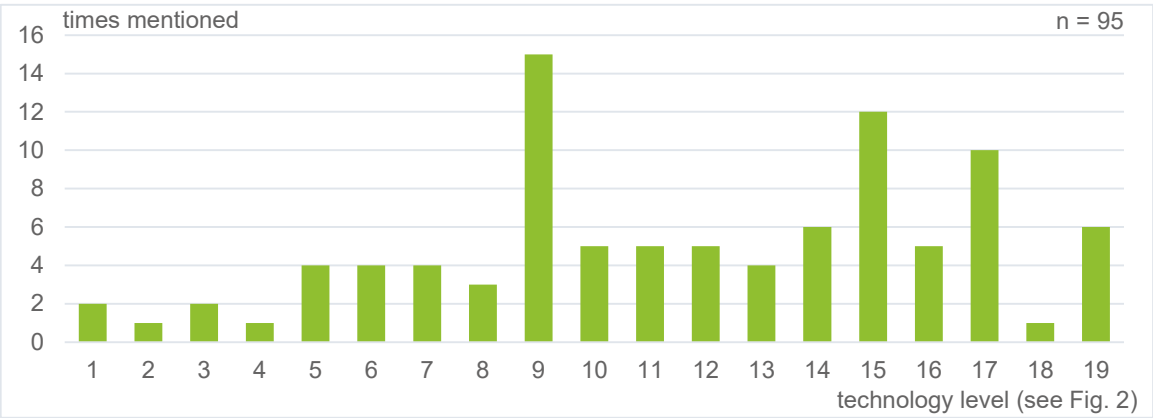

Figure 3: Results of the self-assessment "What does AI in education mean to you?"

Table 1 presents the results concerning the items asking for the attitude towards AI. The largest differences in the average response to the statements are found at item C6 (AI-based applications could especially support learners with special educational needs) with 0.56 points and C8 (I am familiar with the topic of AI) with 0.46 points.

While women tend to agree more with the statement C6, it is the men in C8 who claim to be familiar with the topic. All in all, the answers underline that AI in teaching is not only a general gain C1 (The use of AI is a benefit for the learners) but can also be a relief for the teachers C4 (AI-based applications could ease my teaching load in the future). Currently, the participants do not feel well-prepared C3 (I feel that my studies have prepared me for working with AI-based technology), state that C8 (In the next 5 years, the topic of AI will become increasingly important in teaching), and agree with the statement that the topic is gaining in importance C7 (I'm familiar with AI). On the other hand, they state that they are prepared to deal with the topic C10 (I am ready to deal with the topic AI). In addition, there is a high correlation between C5 (I think it makes sense to use AI in teaching) and C6 (In the next 5 years, the topic of AI will become increasingly important in teaching.). Regarding C9 (I consider the use of AI in teaching to be problematic) it can be said, that, like C2 (I see additional work coming my way using AI in teaching) the participants of the peer-to-peer survey slightly agree.

Table 1. Attitude towards AI

	Age & Attitudes	Gender & Attitudes	General Approval Ratings	
Criteria	Pearson's r | p-value	Pearson's r | p-value	M | SD	Female | Male
C1 benefit	- 0.215 | 0.981	- 0.233 | 0.988	2.94 | 0.700	3.07 | 2.74
C2 work	0.093 | 0.187	0.215 | 0.019	2.76 | 0.859	2.60 | 2.97
C3 able	- 0.112 | 0.859	0.106 | 0.155	1.64 | 0.757	1.58 | 1.74
C4 relief	- 0.065 | 0.733	0.028 | 0.393	2.84 | 0.624	2.87 | 2.85
C5 use	- 0.200 | 0.973	- 0.181 | 0.960	2.87 | 0.718	2.98 | 2.72
C6 special	- 0.093 | 0.811	- 0.354 | 1.000	3.07 | 0.782	3.30 | 2.74
C7 weight	- 0.153 | 0.930	0.079 | 0.226	3.21 | 0.742	3.16 | 3.28
C8 familiar	0.099 | 0.171	0.269 | 0.004	1.88 | 0.849	1.69 | 2.15
C9 change	- 0.239 | 0.989	- 0.066 | 0.736	2.66 | 0.849	2.30 | 2.41
C10 deal	- 0.046 | 0.670	0.096 | 0.178	3.18 | 0.753	3.11 | 3.26

The initial assumption that there are correlations between the classification of AI and the attitude towards using AI in education (H1) can be confirmed by the questionnaire. All in all, students for whom the threshold of AI is higher are more negative towards the use of AI in education (C1; $r = -.236$, $p < .05$) In particular, they feel less comfortable through prepared the course for work with AI-based technologies (C3; $r = -.258$, $p < .05$) see less of a workload relief in AI systems (C4; $r= -.296$, $p < .01$) and appreciate the importance than students with lower acceptance of AI (C7; $r = -.210$, $p < .05$).

4.2 Design and integration of peer-to-peer workshops on AI

In the course of the design and implementation of peer-to-peer workshops addressing AI-related competences, additional learners' reflections were collected. All in all, in the last two semesters 110 students from engineering faculty and technology teaching participated workshops on topics like IoT (Raspberry, Arduino), 3D-Printing, Virtual Reality, and the basics of AI \ NLP. Further publications are planned in this regard [21].

A key observation regarding the assessment of prior knowledge is, that participants had relevant prior knowledge of mathematics and statistics, which has so far not been effectively linked to the AI topics, methods or applications. Hands-on experiences, like here, are taken in addition to the general workload of the semester. Regarding the research questions established in section one, the analysed learners' and tutors' feedback revealed that (1) research-oriented activities including questions on the topic of AI can be applied by students on a high-quality level, (2) prior statistical knowledge is currently not connected with AI topics. Here, AI- or, to be more specific, NLP-based assistant systems offer multiple points of reference to integrate hands-on activities.

5 AN NLP-BASED APPROACH TO INTEGRATE AI METHODOLOGY IN EE

The following section provides answers for the previously stated research questions based on the generated results and therefore outlines a first modular approach to the integration of AI methods in the context of EE by designing a tailored lerning activity in the context of an implementation and reflection of a cognitive assistance system.

5.1 How can AI help to foster data literacy?

Data Literacy (DL) refers to the ability to critically analyse and interpret data, to apply procedures and methods in the context with the collection, management, evaluation and application of data in order to extract knowledge and value from data sources [22]. The overall importance of DL became more and more observable since the curricular integration of learning opportunities focused on the application of the data-rich basic technologies in context with competences for industry 4.0, e.g. Internet of Things. [23]. Due to a significant overlap of competences, DL is considered to be one of several critical literacies, mind and skillsets, which in some instances build upon each other. This refers to e.g. information and science data information, statistical, computational, machine learning, visitational and also ethical or critical literacy frameworks. Today, DL can be described as a focus area of competence development, also due to the further increasing relevance of data science [24]. While DL is an enabler to transform information into actionable knowledge and become able to act, there is a tremendous requirement for learning opportunities that offer low threshold scenarios for an application of relevant technologies, like cognitive assistant systems. Furthermore, these settings should include an accompanying reflection of the impact on the before mentioned concepts to gain metacognitive competencies within problem-oriented, project-based and interdisciplinary learning venues [25]. In order to initiate these reflection processes, in the sense of individualized learning and the assessment of the current level of competence acquisition, assistance systems based on AI technology provide an excellent vehicle to support both on part of the teachers and the learners.

5.2 How can AI help to foster motivation?

The goal-setting theory offers important insights into how to promote student motivation. [26] The four main moderators are ability, task complexity, performance feedback, and goal commitment. AI-based technology can help to address each of these points and thus promote the motivation of students. Ability means that learners

must have the necessary knowledge to solve a task. It is difficult for teachers to find out whether all their students have the necessary skills to complete a task, especially if there are a large number of students. An AI-based assistance system that monitors and evaluates the competence development of learners over a longer period of time can ensure that learners in the game only get tasks that they are able to solve at all. Furthermore, it is crucial that a task is not only generally solvable, but also that the learners are neither under- nor overchallenged. From a didactic point of view, it is often useful to give the learners a lot of freedom in their own development of new knowledge and to promote self-learning processes. Some students, however, quickly feel overtaxed by less structured learning processes, while learners may feel undertaxed in overly structured learning processes. It is difficult for teachers to know and take into account individual abilities. By observing the working methods (and possibly biometric data) an AI-based assistance system is able to consider the right degree of complexity for each student. Continuous feedback also has a positive effect on the motivation of students in learning processes: The better students know whether they are on the right track, the better they can adapt their strategy and achieve motivating success. An AI-based assistance system can analyze individual work steps of the learners and predict expected work steps and provide timely support before learners become demotivated by failure. Goal commitment is an aspect that is too often neglected in higher education teaching. In order to develop motivation, a goal that learners have set for themselves is necessary. Teachers set their focus on their learning outcomes, but usually not on the individual goals of their students, such as passing an exam, getting a good grade, obtaining a degree or being among the better students and thus possibly receiving further rewards. These are usually medium to long-term goals. But the more students are aware of their own and short-term goals, the more motivated they are to put work into achieving them. This is too much effort for teachers, but an AI system can help to get a picture of the overall goals of individual learners and help them to break down these goals into short-term goals and relate them to current tasks. All in all, an AI-based assistance system is thus more efficient in addressing the four main factors of the goal setting theory in higher education teaching and actively supporting students in promoting their motivation.

5.3 A Tutor for Artificial Intelligence supported Learning in Engineering

A **T**utor for **A**rtificial **I**ntelligence supported **L**earning in Engineer**ing** or *TAILing* describes an approach of the curricular integration of AI-related topics, while focusing on meta-cognitive competences in the context of data literacy and motivation (fig. 4). This Approach is built upon the idea of self-directed and AI-assisted learning, where the implementation of an AI-/NLP-based assistant serves as a vehicle for application. Here, learning activities in interdisciplinary teams to (co-) design such a tool offers vast possibilities of reflectional tasks for the learners, can be used as a mediator between learners' attitudes towards the use of AI, their peers and the instructors and serve as an accompanying consultant for the teachers. In using several NLP-related open-source repositories, the learners can create an AI assistant system that monitors and evaluates individual competence development throughout the course on a basic level.

They build their personal learning assistant on their own and by doing so, they reflect on the compatibility of data interfaces, data sources, questions of ethics, and more.

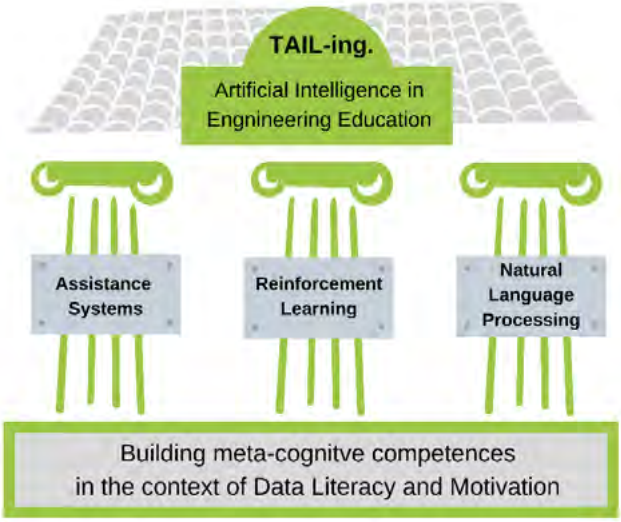

Figure 4: Outline of the pillars and the foundation of TAILing

The course design is planned as an interactive (h5p), supervised and asynchronous online course, which ties into the learners prior knowledge specific to their curriculum and thus enables the development of basic competences in the context of AI and the aforementioned meta-cognitive competences regarding data literacy and motivation. The course is interlocked with interdisciplinary workshops in a Makerspace, which promotes a co-creative and project-oriented application of AI-related basics. Following the successful participation in the "AI basics" course (60 hours | 2 ECTS), the in-depth blended learning course "Decision-making with AI-based information" will be taken, which transfers findings of NLP to implement an AI tutor for EE (90 hours | 3 ECTS).

6 SUMMARY

So far, the analysis of the potential of AI-based assistance systems in higher education teaching has focused on students' activities. This makes sense in some respects, but also implies an understanding that teachers could potentially become superfluous in such scenarios. In fact, the question of what role teachers will play in increasingly AI-supported teaching is becoming more important, given that they will be relieved of the essential tasks of student support. Will they remain important in supporting learning processes or in evaluating learning outcomes? Or is their role limited to curricular aspects, the definition of learning goals and the development of learning modules? Will they (have to) work together with an AI system in order to control the didactically meaningful support of learners? What is the interaction between teachers and the AI-based systems like? Will teachers and engineers in future need an AI assistance to help them design their AI assisted teaching? Research on and development of AI-supported learning processes should take these issues even more into account. In addition, key questions regarding the impact of the increasing dependency on AI-based information systems, concerning data literacy and motivational aspects, need a profound answer to meet the requirements of future AI-influenced venues of work.

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PREPARING TEAMS OF NEURO-TYPICAL AND NEURO-ATYPICAL STUDENTS WITH A COMPUTER ORCHESTRATED GROUP LEARNING ENVIRONMENT FOR COLLABORATIVE WORK: A MULTI CASE STUDY

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ABSTRACT

The number of students entering higher education with a diagnosis of Autism or ADHD is on the rise, and within engineering it is higher than the sector average. This calls for understanding how these students experience higher education and how best to support them in overcoming socio-communication challenges and developing the teamwork skills required by industry. This article investigates a novel Computer Orchestrated Group Learning Environment (COGLE) that orchestrates content delivery and learning in small face-to-face groups of neuro-typical (NT) and neuro-atypical (NAT) engineering students. This research uses a literal replication logic, where multiple similar case studies contribute evidence towards analytical generalisation and transferability. COGLE is used in the first case in a flipped classroom setting and in the second case within a Project Based Learning setting. The teamwork skills of NT and NAT students were compared. Normalised learning gain (NLG) scores were computed using pre and post test data. Qualitative comments provide insights into the experience of NT and NAT students. Key lessons learnt highlight the importance of learning together to master content before engaging in collaborative activities such as peer instruction commonly within flipped classrooms and teamwork within Project Based Learning. In both case studies, NT and NAT students had comparable NLG scores and developed their team working skills. This research shows that both staff and students can benefit from COGLE as it prepares students for collaborative working by improving both technical knowledge and team working skills freeing up staff to focus on guiding and supporting student learning.

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1 INTRODUCTION

1.1 Increase in collaborative approaches within Engineering Education

Collaboration skills are considered important within most professions. In engineering, team working skills are considered as one of many crucial skills for the success of any real-world open-ended project. Higher engineering education curricula, in the UK and elsewhere, have seen recent changes in response to the calls from industry and professional bodies to increase focus on problem solving and team working and using collaborative approaches to develop these graduate skills [1-3,8-9]. Learning in groups within engineering has been shown to have greater achievement, with a moderate effect size (d=0.25), than learning individually [4]. As a result, collaborative approaches such as Flipped Classroom (FC) and Project Based Learning (PjBL) have gained popularity over the years within Engineering Education [5-6]. In FC, students are expected to prepare the content themselves and take part within collaborative active learning activities in class [5, 7]. In PjBL, students work collaboratively in a group, on a defined real-world project and are expected to learn what is needed to deliver the project. The popularity of such approaches has meant that there has been a shift in the expected role of the academics from being a 'sage on the stage' disseminating information to a more supporting 'guide on the side' role [6]. There are, however, many challenges that come with this shift in expectations and practice.

1.2 Challenges collaborative approaches bring to Engineering Education

Without theoretical knowledge that underpins the change in their role and the skills needed by staff in facilitating groups, staff often face challenges when adopting PjBL or FC approach [6-7]. Not just staff, the students also find it hard to develop and use interpersonal skills if they have not had and do not have access to any formal team skills training [6-7]. Furthermore, PjBL is resource intensive and requires more staff to facilitate teams and to put in extra effort in guiding students. This is particularly important where students are from multicultural backgrounds [6]. As PjBL needs more resources from schools or departments, it can lead to a reduction in institutional support for such approaches over time [6]. This puts any benefits of the PjBL approach, where realisable, at risk. Likewise, students find it time consuming and hard to prepare on their own in the FC approach. Due to limited student preparation, staff find it tricky to carry out their planned collaborative activities in a way that is fair and benefits the entire class [10]. In practice, staff often find themselves performing both the roles of teacher and facilitator, especially when students complain about not being able to learn or work on their own on open-ended real-world problems without being taught first and a similar criticism is faced for flipped classroom approach too [6,10].

More and more neurologically atypical students (NAT) are entering higher education as diagnosis rates are on the rise. NAT is an umbrella term that includes Attention Deficit Hyperactivity Disorder (ADHD) and Autistic Spectrum Disorder (ASD)

students. Researchers have claimed that NAT students are more likely to study engineering and technology courses [11]. As a result, it is very likely that most engineering cohorts will have a mix of neurologically typical (NT) and neurologically atypical (NAT) students learning together. Formally diagnosed, or not, such students face socio-communication challenges that may affect them in realising their full potential [11]. Social interactions and communication are crucial for success within PjBL and FC activities, making it harder for NAT students to succeed. In addition, reasonable adjustments are needed by law and teaching NT and NAT students alongside each other poses problems [12]. In practice, the demands of PjBL and FC can put most students under pressure, including NT, diagnosed NAT and those that remain undiagnosed [13]. Therefore, the challenges faced in social interactions and communication within group work can limit the success of FC and PjBL for NT as well as NAT students.

1.3 Context and Rationale

Both FC and Project based learning are used within the School of Energy and Electronic Engineering at the University of Portsmouth. Here, teams of students may need to collaboratively design, build and test say a communication system as part of a PjBL project or collaboratively discuss design challenges related to electronic subsystems within FC activities. Disability data from Higher Education Statistics Agency (HESA) show 0.9% (male), 0.2% (female) & 3.6% (other) current UK domiciled students have ASD or other social communication disorder [24]. Research suggests females can be better at masking social behaviours common in NAT and are not being diagnosed as a result [22-23]. As NAT students are more likely to study engineering [11], supporting the already small % of female students entering engineering degrees becomes even more important. In the last three years alone there has been an increase in students with specific learning disabilities (including ADHD) and ASD to 15.7% and 1.2% respectively within the school. This increasing trend in NAT students joining our courses, combined with potential benefits to NT students from an intervention that can cater to both NT and NAT students learning together, provides the rationale for this study. COGLE may provide an approach to teaching that is inclusive for students with socio-communication challenges and enhancing their learning and team working experience.

2 METHODOLOGY

2.1 The intervention: Computer Orchestrated Group Learning Environment (COGLE)

COGLE was developed within the School of Energy and Electronic Engineering at the University of Portsmouth. It orchestrates small face-to-face groups of students watching together short videos followed by orchestrating them practice related questions till they all achieve group-wide mastery, i.e. they can all show that they understand the content by answering questions. During each session students are paired several times to carry out peer instruction with those who get the questions wrong. COGLE runs within a web browser with videos hosted anywhere on the web,

for example YouTube®. The questions are carefully designed to encourage discussions between students. To achieve group-wide mastery all students in a team have to get 10 questions correct in a row. Anyone making a mistake resets this target and they must start again. COGLE is able to identify mistakes that are prevalent within the group, thanks to the careful question design. It plays a remedial video based on the most prevalent mistake in the group.

2.2 Underpinning pedagogical theories

Peer Instruction is widely used within higher education to help students learn from each other in real-time environments [14-15]. The COGLE platform automates the grouping of learners needed in PI in a democratic and inclusive way. This gives a chance to all students, including NAT students, to engage in peer learning. It is hoped that mastery of content [16-17], when extended in a group-wide sense ensures a higher learning gain for learners in groups for both NT and NAT students alike. The repeated orchestrations have the potential to aid the internalisation of team working skill, as predicted by the *Script guidance theory* [18].

2.3 Research site, participants and research design

Two Electronic Engineering modules, one at level 3 (first year of foundation degree) and one at level 4 (first year of undergraduate degree), were chosen where FC and PjBL activities were being used respectively. This formed the basis for students from level 3 to use COGLE to prepare for FC activity and level 4 students to prepare for PjBL task. The module co-ordinator confirmed observing similar challenges as noted above in both the modules. The two modules also benefit from covering the same basic material in the early parts of the course to ensure students are introduced to basics of electronics before moving on to advanced topics in level 4 module. In order to investigate the potential of COGLE in supporting NT and NAT students together within a real-world setting participants were invited from these two modules to join the study.

The study was approved by the University's research ethics committee and students from the two cohorts were invited to come forward, in particular those with ASD and ADHD, and give informed consent for taking part in this study. This was the only way we were allowed to reach out and recruit students and as no access to entire cohort was permitted by the ethics committee. A total of 19 students joined the study, 9 from level 3 foundation course in Engineering and Technology and 10 from the BEng Electronic Engineering course. Three foundation students did not complete and left the study mid-way as one of their teammates, an international student, went back without giving any explanation leaving a group of 2 who did not wish to continue. The remaining 6 level 3 students were put in teams of 3 each randomly and were put into the FC case-study of the study. One level 3 student self-declared themselves as autistic. The remaining 10 level 4 students joined the PjBL case-study and were put in random teams of 3 or 4 students. In level 4 one student was diagnosed as Autism

(comorbid with ADHD) and one student had ADHD. All 16 students completed the study.

Students on the FC case-study learned together for 4 two hrs sessions in their designated teams prior attempting a two hour FC collaborative design challenge in their designated teams. Students on the PjBL case-study, did the same 4 two hour sessions and in addition 3 further two hour sessions (7 sessions in total) to master the content needed for the PjBL task in their designated teams. The FC task involved designing a bass and treble filter circuit to be used as input to a head-phone amplifier. The PjBL task was more complex where the students were required to design both the filter circuits as well as the headphone amplifier within the same two hour time. The content used in the FC case-study was also used in the PjBL case-study in addition to more content on advanced topics as needed for the PjBL project. The two case-studies thus formed part of a literal replication multi-case study design used here [19]. The use of orchestrated group-wide mastery in two different case-studies should generate robust evidence advocating for using such an approach with NT and NAT students within Engineering Education settings to enhance their knowledge and internalising team working scripts used within COGLE.

2.4 Methodology for evaluation

One of the challenges reported above within FC and PjBL contexts is to do with students finding it hard and time consuming to prepare content before taking part in the collaborative activities. If students have mastered content using COGLE and they understand the concepts needed within the collaborative activities, they are more likely to feel able to contribute to the FC and PjBL activities and complete the tasks set within each. The automated nature of COGLE solves this and the resource intense issue in PjBL, but to prove that this intervention can actually teach in an efficient way, this research uses a pre post-test designed in the two cases presented. A test comprising questions similar to the ones used within COGLE, but without the multiple options, was used to measure the students' knowledge before and after the COGLE sessions and before going into the FC or PjBL activity. Normalised learning gain was computed using the formula stated in *Eq. (1)* using the pre and the post test scores of each student in the study.

$$Normalised\ Learning\ gain = \frac{Posttest - Pretest}{100 - Pretest} \quad (1).$$

Appropriate statistical methods like t-test and effect size are calculated as the data collected was normally distributed to test the null hypothesis as follows:

H_0 - There is no statistically significant difference between a student's learning gain before and after the use of COGLE.

It is also predicted that the learning gains of NT and NAT students will be comparable. As the number of NAT students was really small, hypothesis testing cannot be used here for this prediction.

Another area where COGLE plays a role is the development of team working skills of the students. After each session the students were asked to complete a survey with free text space to answer the following questions.

1. Describe what did and did not go well, when prompted by the system, to teach or explain to other student(s) a concept.
    a. Also, describe how the system made you or others in your team contributed to improving or worsening the situations you described as “did" or "did not go well” above respectively.
2. Describe what did and did not go well, when prompted by the system, to learn from other student(s), a concept.
    a. Also, describe how the system made you or others in your team contributed to improving or worsening the situations you described as “did" or "did not go well” above respectively.

In addition, qualitative data was collected through an hour long interview. The interviews were transcribed verbatim by professional transcriber. This paper only presents initial analysis of the quantitative data and present some key themes from the qualitative data from the daily survey that was analysed using grounded theory inspired thematic analysis [20]. The analysis is still underway and will be presented in a subsequent research article.

3 RESULTS

3.1 FC Case

As there were only 6 students in this case, a test for normal distribution was conducted before any statistical methods were used to analyse the results. Table 1 shows the raw data along with the normalised learning gains (NLG) for each student. All students including the autistic student have large positive NLG values.

Table 1. Raw scores and Normalised learning gains in the FC case

Student	Pre-test %	Post-test %	Normalised Learning Gain	NT/NAT
A0	*0*	*43.48*	*0.43*	NAT
A1	*43.48*	*60.87*	*0.31*	NT
A2	*43.48*	*73.91*	*0.54*	NT
A3	*17.39*	*60.87*	*0.53*	NT
A4	*17.39*	*30.43*	*0.16*	NT
A5	*34.78*	*82.61*	*0.73*	NT

The Kolmogorov-Smirnov test of normality was performed on the pre and the post test data. The p-value was 0.89036 (>0.05) for the post test score and p-value for the pre-test was 0.91253 (>0.05). This means that the data does not differ significantly from that which is normally distributed and therefore *t-test* was carried out with a *t value* =

5.416328 and a p-value=0.0029, meaning the result is significant (p<0.001) and we can safely reject the null hypothesis here. This equates to a large and significant effect size of 1.7803 with confidence interval CI (0.43, 3.11).

The results indicate that all students were able to learn using COGLE. The lowest value of NLG was 0.16 and the maximum was 0.73. The autistic student, A0, has a NLG of 0.43. The ASD student's score is comparable to other NLGs measured here, indicating that NT and NAT students experienced similar benefits from using COGLE. Within their team, which consisted of student A0, A1 and A2, the NLG of the ASD student is comparable to the range of scores achieved by this team. These results indicate that all students were able to learn using COGLE efficiently without the needs of facilitating staff.

3.2 PjBL case

As there were only 10 students in this case, a test for normal distribution was conducted before any statistical methods were used to analyse the results. Table 2 shows the raw data along with the normalised learning gains (NLG) for each student in this case. All students including the autistic and the ADHD student have large positive NLG values.

Table 2. Raw scores and Normalised learning gains in the PjBL case

Student	Pretest %	Posttest %	Normalised Learning Gain	NT/NAT
A0	26.47	85.29	0.80	NT
A1	23.53	44.12	0.27	NT
A2	35.29	70.59	0.55	NT
A3	29.41	52.94	0.33	NT
A4	14.71	55.88	0.48	NT
A5	26.47	55.88	0.40	NT
A6	35.29	61.76	0.41	NT
A7	26.47	55.88	0.40	NAT
A8	35.29	73.53	0.59	NAT
A9	38.24	70.59	0.52	NT

The Kolmogorov-Smirnov test of normality was performed on the pre and the post test data. The p-value was 0.63674 (>0.05) for the post test score and p-value for the pre-test was 0.64631 (>0.05). This means that the data does not differ significantly from that which is normally distributed and therefore *t-test* was carried out with a *t value = 9.697417* and a p-value=0.00001, meaning the result is significant

($p<0.0001$) and we can safely reject the null hypothesis here. This equates to a large and significant effect size of 3.369 with confidence interval CI (2.00, 4.724).

The results indicates, all students were able to learn the basics as well as more advanced topics in electronic engineering using COGLE. The lowest value of NLG was 0.27 and the maximum was 0.80. The autistic student, A7, has a NLG of 0.40 and the ADHD student, A8, has a NLG of 0.59. Both are within the range of NLGs measured here, indicating that NT and NAT students experienced similar benefits from using COGLE. Moreover, Team 3 consisted of student A6, A7, A8 and A9. The NLG of A7 is at the lower end of the range of scores achieved by this team. A8 seems to have benefited greatly by using COGLE, more so than other students. Both scores are still close to each other and comparable to other NT students in the study. Much like the previous case, the results here too indicate that all students were able to learn the basics as well as more advanced topics in electronic engineering using COGLE efficiently without the need of facilitating staff.

The daily survey data was focussed on each session during the learning together phase in both case-studies. The data was coded line by line using inductive coding, codes were then analysed to identify themes and sub themes within the data. *Mastering the content together* with several orchestrated interactions and support provided by COGLE encouraged students to overcome initial *social awkwardness* and *improve their connections with each other.* This way they *learned better together* as shown in the learning gain data above. The many interactions orchestrated by COGLE and those that were self-orchestrated *brought the teammates together*, preparing them for teamwork that was to follow. COGLE also helped *arbitrate conflicts* by pairing the relevant peers for discussion and supporting their discussion with *correct answers* and *remedial videos*. Practicing group-wide mastery in this way meant they *internalised* the approach of discussing topics with each other with an open mind and used it during the un-orchestrated FC and PjBL task activity. A sample of qualitative comments from NAT student show how COGLE helped the NAT students *master the content together* and *prepare for the team work* that followed as shown by free text comments from the daily survey that captured key events that took place in each session:

- "...*worked together as a team to master* the questions...both team mates explained a concept, *each one did it differently* so *helped* with *improving my knowledge*" (ASD student, Level 3)
- "It allowed us to *discuss with each other* how to *get the correct answer* and as such allowing us to cooperate better due to *our improved connections with each other*" (ASD student, Level 4)
- "It was useful in *highlighting* simple *errors we had made* individually and *helped us to understand the material*" (ADHD student, Level 4)

The student with ADHD benefitted by an enhanced understanding of the topics, in particular as COGLE highlighted the small mistakes he made, as

he was prone to, due to his disorder. The ASD student felt that they were able to connect better with others in using COGLE.

The NT students had similar experience too as shown below:

- "The system made it clear as to what was wrong and right giving a percentage of who answered it correctly and incorrectly. *It stopped arguments* this way as the answer was projected to the whole group and the *participants who got it right were allowed to explain it* to the rest of the group." (NT teammate of ASD student, Level 3)
- "The *system recommended that we not only discuss with our group mates*, but watch a *video* which was related to the problems we were getting stuck on. This really helped in the long run and *helped us finally achieve mastery*." (NT student, Level 4)
- "It [COGLE] *helped us to work as a team* to get *all the questions* right." (NT student, Level 4)
- "we were *all* able to say our ideas to each other and we made sure we *were all on the same page* and if we didn't get it still *we were able to watch a video and discuss with each other* about the video to make sure *we all understood* this really *helped when the style of questions* were repeated because we then knew how to solve the questions" (NT teammate of a NAT student, Level 4)

The NT students also benefitted by an enhanced understanding of the topics, in particular as COGLE supported them with remedial videos and by promoting the exchange of diverse views between all students repeatedly. The NT student felt that they were able to connect better with others in using COGLE as it helped arbitrate conflicts and invited all students to have their say. The quotes above and the quantitative data presented earlier both point towards the successful teaching and learning that took place within COGLE in the two cases. It also shows that NT and NAT students found the support provided beneficial for learning and team working.

4 Discussion and implications for engineering educators

The two cases provide repeating results adding strength to the claim that COGLE is able to support a mix of NT and NAT students where both acquire domain knowledge and team working skills. Having mastered the content needed for the FC or PjBL tasks, through learning together in COGLE, COGLE enhances self-efficacy and develops the skills needed by the students for team working. They arrived ready as a team to work on collaborative tasks set for them and all teams completed their set tasks with scores over 70%.

The benefit of COGLE is not just for students, staff can benefit too. After a one off investment in time in creating video content and questions, COGLE can be deployed any number of times and for any number of teams within the limits of the physical

space within the school. COGLE can be used over distance too but this was not studied in this research. Using COGLE for FC preparation changes what may be commonly understood as the Flipped Classroom approach. Here, instead of expecting students to learn individually at home, students can be programmed to come in for preparatory sessions, where minimal supervision and no teaching is actually needed as this is orchestrated by COGLE instead of an academic. We call these sessions as software assisted learning together sessions. During the FC activity, academics orchestrate collaborative active learning tasks, such as peer instruction, based on the content already mastered within COGLE sessions. Likewise, for PjBL the students can learn together with minimal resources before attending their PjBL lab sessions and team meetings. In both cases, the time with the academics can be more meaningful as the class and the groups are already prepared for collaborative tasks and projects.

5 SUMMARY AND ACKNOWLEDGEMENTS

This work presented the evaluation of student performance and team working in collaborative settings such as FC and PjBL after using a novel group learning environment, COGLE. It shows how both NT and NAT students were able to master content and come together as a team as they prepared for collaborative activities. They also completed the FC and PjBL activity that followed successfully. This means that COGLE was able to support NAT students in overcoming socio-communication challenges in an inclusive manner whilst learning alongside NT students. Staff can also benefit from the use of COGLE as it frees them from having to teach instead of focussing on guiding and student needs. COGLE prepares students before they set foot on collaborative tasks that require both team working skills and mastery of technical knowledge, the two most important pillars in engineering education. The effect size is greater than other studies involving learning in teams [4]. The learning gain results are generalisable to the population as shown by the rejection of the null hypothesis for the two cases. The two cases show the transferability of the intervention design for mixed groups of NT and NAT students in terms of the team working skills and other themes in the qualitative comments. Likewise, comparing results from COGLE based case-study with traditional environments or student orchestrated groups will enhance the claims made in this study with regards team working skills. During the search for studies involving team working skills development of NT and NAT student together, none were found. Multiple studies involving larger cohort size and in different engineering disciplines can help with the transferability of the results further.

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CONTINUOUS REFLECTION USING AN E-PORTFOLIO IMPROVES STUDENTS' LEADERSHIP BEHAVIOUR

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ABSTRACT

Knowledge, skills, and abilities in communication and project management and the application of these basics to facilitate teamwork and leadership are necessary for both professionals and students of higher education in all science and engineering fields.

Leadership education has usually been limited to simple acquisition of knowledge in a classroom-setting, and a major issue has emerged concerning transfer of classroom-acquired knowledge into real-life practice. Leadership education has been conducted for ten years for first-year Master's students at the Graduate School of Engineering and Science at the Shibaura Institute of Technology. The program has five modules: knowledge, training by simulation, real action, reflection, and assessment. Because students have limited opportunities to learn from real leaders and demonstrate leadership behaviours, we utilised a simulator to enhance students' experiences in a safe environment by having them review their own behaviour with an e-portfolio. Students are likely to be less hesitant to take leadership initiatives after repeated simulations. The purpose of this study was to positively change leadership behaviour of students by allowing them to practise reflection with the e-portfolio. The students followed prompts concerning reflection on their behaviour in the e-portfolio, during a seven-week period. To verify the educational outcomes of learning, questionnaire surveys were conducted on 'changes in interpretation of leadership concepts,' 'changes in leadership behaviour through continuous recording in the e-portfolio,' and 'leadership self-efficacy.' Results highlighted the potential of continuous reflection using the e-portfolio for positive changes in learners' leadership behaviour.

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1 INTRODUCTION

All engineering students need to develop their important skills of leadership in project management. Leadership education has been conducted for first-year students of the Master's program at the Shibaura Institute of Technology's Graduate School of Engineering and Science for over ten years. Because students have limited opportunities to learn from hands-on leadership experience, we utilise a simulator to increase students' experience in a safe environment. A student is less hesitant to take leadership actions following repeated practice in simulations. The program has five modules: knowledge, training by simulation, real action, reflection, and assessment. The e-portfolio was introduced to invite students to review their behaviour. Leadership, which is the core of this research, is a highly interdisciplinary theme that has been studied in multiple fields such as psychology, business administration, and educational technology. At present, leadership research is being transformed from exploring what leadership is to the development of leadership. Learning from experience is gaining attention as an excellent way for leaders to grow, and empirical research on leadership development through experience learning is progressing. These studies have shown the importance of reflection on experience [1]. The process of reflection is important to promote effective reflection from experience. For the learning through experience process, Kolb constructed a four-stage learning cycle: 'concrete experience', 'reflective observation', 'abstract conceptualisation', and 'active experimentation'. This model has recently been widely used in teacher education and nursing [2]. Many universities in the United States, which is known for good leadership education, use the Social Change Model of Leadership Development as a basis for building programs. One of the seven components of the model, the consciousness of self, is positioned as the basis for realising all other components. Effective reflection methods for raising self-awareness include conscious observation of current self-thinking, feelings and behaviour, receiving feedback from others, and keeping a diary [3]. As described above, it is clear that reflection is important in the process of turning experience into learning in leadership training. However, the methods and processes of reflection to enhance positive leadership behaviour have not been clarified. This research focuses not only on shallow reflections of only the facts experienced, but also on deep reflections that change student behaviour. The central question in this study is 'What kind of process reflection is effective in bringing positive change to student leadership behaviour?'

2 METHODOLOGY

2.1 Definition of leadership

In this education, leadership is defined as a relational process of people attempting to accomplish change or make a difference to benefit the common good together [4]. In addition, leadership is not an ability bestowed upon a special person, but rather for everyone to exhibit and develop.

2.2 Leadership educational objective and the level of study

Educational objective

The educational objectives are shown below:

- To understand the systematic knowledge needed when implementing project activities.
- To practise skills and leadership within the technical areas of science and engineering.
- To understand one's own skills and to set up a behavioural objective.

Style of teaching and learning

Education and learning styles are shown in Table 1.

The outcome of learning is gradually established in the following order: 1. Knowledge → 2. Consciousness → 3. Action → 4. Mastery.

Table 1. Learning styles combined for leadership education.

		Lecture	Simulator	Practice
Merits		Deep knowledge	Many simulated experiences	Real experience
Demerits		Passive learning	Virtual	No second chance
Outcome of learning	1. Knowledge acquisition	xxx	x	
	2. conceiving leadership	xx	xxx	xx
	3. Acting		xx	xx
	4. Mastery		xx	xxx

** The number of x represents the extent of suitability of each teaching methodology for a desired outcome. The higher the x score, the more suitable the teaching methodology is for a desired outcome. The most suitable methodology for varying types of outcome is as follows: a lecture, for acquisition of the knowledge; a simulator, for conceiving leadership; and practice, for achieving mastery of skills and techniques.*

Although a lecture is suitable for giving systematic knowledge, it is difficult to include activities in which students can practise action. A simulation exercise has the effect of raising awareness of daily improvement and the necessity for new action as a result of self-reflection. Although practice aims at the mastery of the skill, a long period of time is required to achieve a learning outcome. Each educational style has a mutually complementary relationship, and they can achieve results by working together. Based on this plan, the leadership educational model in Figure 1 was designed.

2.3 Leadership education model

The leadership education model (Fig. 1) has five modules: knowledge, training by simulation, real action, reflection, and assessment [5]. At the start of a program, diagnostic evaluation is conducted. Next, a student enters a cycle of skill acquisition.

The first step is for students to gain knowledge in the leadership arena through lectures. Then, they utilise simulation to experience leadership actions many times. Simulation provides a safe environment in which they can try many different approaches in taking leadership in various situations. A simulation exercise has the effect of raising awareness of daily improvement and the necessity for new action as a result of self-reflection, all of which stem from the various virtual experiences.

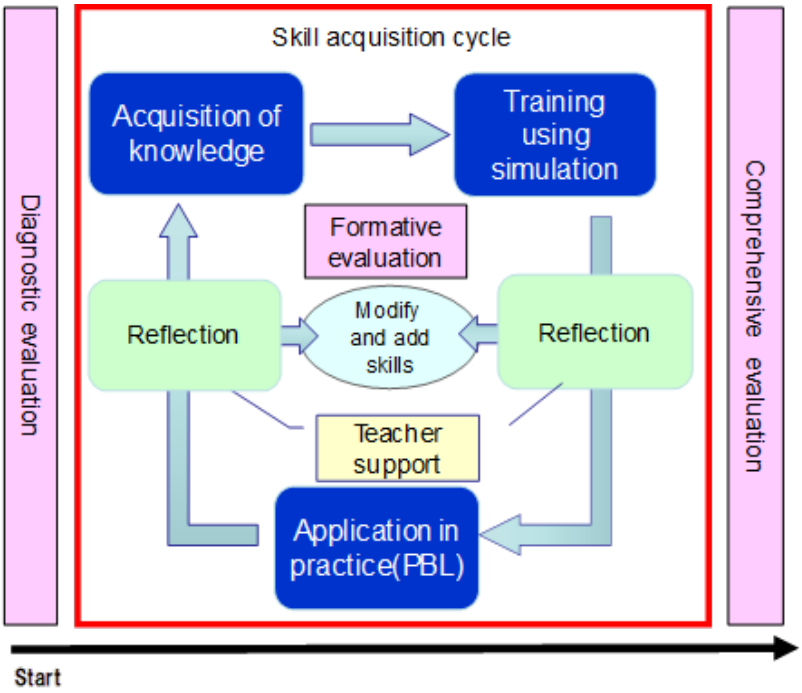

Fig. 1. Leadership education model

Table 2. Leadership behaviours targeted in PBL activities

#	Four components	Specific leadership behaviours
1	Goal setting and achievement	I can devise my work to contribute to an activity in a project
2		I can understand specific situational requirements and encourage project members to achieve their goals
3		I can contribute to a project and achieve results through work
4	Communication and problem solving	I can share knowledge and technology with a project member positively, and can strengthen a mutual relationship
5		I can discern the cause of a problem, acquire pertinent information, and determine a solution
6		I can carry out activities for the smooth progress of a project
7	Proposal of ideas and ability for planning	I can coordinate socially relevant research tasks and plant the seeds of scientific innovation
8		I can propose an idea with confidence in a timely manner

9		I can create a plan foreseeing short- and long-term research results
10	Understanding the situation/building relationships	I can manage my and others' ability to cope with high pressure situations or rapidly changing environmental conditions
11		I can engage a project member in conversation, listen attentively and positively, and show sympathy
12		I can raise motivation by managing a project member's level of stress

In the next step, students as a team utilise PBL (Project Based Learning) so that the above simulated experiences can help them show leadership. Students can apply their leadership training in actual projects, and this increases their leadership skills. It is highly effective to apply conscious leadership to a project aimed at a specific goal in limited circumstances. Table 2 shows the specific leadership behaviours that students aim to practice in PBL activities. This education repeats both of the steps above, thus raising leadership abilities in an upward spiral. Furthermore, the learner reflects on the simulated experience and the action in practice, and identifies the skill correction component and the skill that needs training. In the end, students complete a comprehensive evaluation. This paper focuses on the reflection component. In particular, this study focuses on individual reflection. The e-portfolio was used as a tool to promote reflection. Over a period of seven weeks, on a weekly basis, students recorded and reflected on their leadership experiences in the e-portfolio.

2.4 Education using simulation

Students who lack experience have huge gaps between knowledge and action and this makes it impossible for them to immediately turn knowledge into action. Therefore, we utilise simulation as a means to bridge these gaps [6]. This simulator was developed with the aim of strengthening interpersonal skills and acquiring leadership skills to involve the members around them in achieving goals. The training of the simulator aims to ensure that repeated thoughts and actions are ingrained in the body and eventually they come out naturally without being conscious of them as actual actions. The simulated experiences that students acquire through repetitive practice can provide a smooth bridge to reality.

2.5 Setting reflection prompts

Students recorded and reviewed their leadership experience in the e-portfolio once a week for seven weeks. The portfolio has the following prompts to encourage reflection:

1) What happened? (What needs improvement?)
2) What were your feelings and thoughts at that time?
3) Where do you think the cause of the failure was?
4) What are the lessons learnt from the experience?
5) What action do you want to try next time for better results?

3 OUTLINE OF SURVEY

3.1 Survey target

The purpose of this study is to clarify changes in students' interpretations of leadership over the course of seven weeks of leadership practice and the effects of continuous recording in e-portfolios.
The subjects of the survey were 89 first-year Master's students in the Graduate School of Engineering and Science, who were trainees in the required subject 'Advanced Systems Engineering'.

3.2 Survey timing and method

A questionnaire survey was conducted at the midpoint of seven weeks of leadership practice (four weeks after the start). The questionnaire was distributed on the Learning Management System (LMS) and the students answered on the LMS. Answering was optional and, as a result, responses were obtained from 22 people (response rate 25%).

3.3 Survey contents

The following four questions were asked in the questionnaire survey.
Question 1: How do you interpret leadership? Has it changed from your previous interpretation?
Question 2: You have recorded your leadership experience and results of your reflections in your portfolio. Please describe how your feelings, thoughts, or actions have changed as a result of this continuous recording.
Question 3: In your leadership practice, how strongly do you feel that you are actually able to implement what you have just learned in your leadership practice? Please choose one from the following: Very strong; Strong; Moderate; Not much; Not at all.
Question 4: How much do you want to improve your leadership? Please choose one from the following: Very strong; Strong; Moderate; Not much; Not at all.

4 RESULTS

The results for Question 1 are shown in Table 3. Regarding the interpretation of leadership, comparison was made between before and during the course (4 weeks after the start). Twenty out of 22 (91%) responded that there was a change, and two with no change.
Thirteen out of the 20 people who changed had perceived leadership as a skill that one person in the team possesses before attending the course. Specifically, there were descriptions such as 'I thought that leadership belongs only to the leader', 'I thought that leadership was an innate ability', and 'One person who puts together a team'. Four weeks later, these interpretations changed to recognition that leadership was a quality for all members of the group, and that skills could be acquired through training. Specific descriptions included 'the abilities required of all members, not just leaders,' 'skills that each member should understand and demonstrate,' and 'anyone can acquire that ability through practice.'

Next, an excerpt of the results for Question 2 is shown in Table 4. This is a description of changes in students' feelings, ideas, and behaviours due to the continuous reflection on leadership experience in PBL activities recorded once a week. Out of 22, 21 (95%) showed specific changes, and one answered no change.
Finally, Table 5 shows the results of Questions 3 and 4. The following two items were cross tabulated: the degree of feeling that following the leadership practice that they were likely to do well; and their willingness to increase their leadership skills. Fifteen out of 22 (68%) were willing to increase leadership. However, in the leadership practice, eight people (36%) answered that they seemed to do well. In addition, all four students who answered that their motivation for improvement was 'very strong' answered that they were 'strong' about the feeling that they seemed able to do well. In contrast, 11 students who answered that they had a 'strong' desire to improve had different results about their confidence that they could do well, specific details were as follows: two people for 'strong', six for 'moderate', and three for 'not so much'.

Table 3. The transformation of leadership concepts through leadership education (excerpt)

#	Before class starts	Four weeks after
1	Charismatic skills that only certain people have	Skills that can be acquired through training
2	What a single leader exercises	Exercise by all members participating in the project
3	How leaders can organise members	Anyone can improve by practising repeatedly over and over instead of innate ability
4	What the best people in the team demonstrate	It can be demonstrated to anyone depending on the training and effort of the person
5	A team needs a single leader	Everyone in the group demonstrates leadership

Table 4. Changes in feelings, thoughts, and behaviours caused by continuing to record in the portfolio (excerpt)

1	In every PBL class, I became aware of leadership. I feel more responsible that I have to be more active in the project than before. I had the habit of thinking about the project outside of class
2	I thought it was important to always look back on my behaviour using the portfolio, reflect on and improve, and gain leadership. At the same time, I feel it is difficult to acquire leadership
3	I have a clear understanding of my shortcomings and what I need to improve next time. It has become clear what action to take during group discussions in the exercises

4	We now take time to look back after the exercise discussions to record in the portfolio. As a result, I feel that the content of the discussion has become more organised and that I have been able to produce various ideas. As I reflected not only on the content of the discussion but also on my actions, remarks, and behaviours, I began to improve areas that I felt needed improvement
5	I have accumulated what I need to gain leadership. In particular, I feel that the depth of discussion, the morale of members, and the speed of work change depended on the presence or absence of leadership. Recently, I have begun to be conscious of paying attention to the other person's feelings during discussions

Table 5. Numbers of responses cross tabulated for Questions 3 and 4.

Question 4: How much do you want to improve your leadership?	Question 3: How strongly do you feel that you are actually able to implement what you have just learned in your leadership practice?					
	1 Very strongly	2 Strongly	3 Moderate	4 Not much	5 Not at all	Total
1 Very strongly	0	0	0	1	0	1
2 Strongly	4	2	1	0	0	7
3 Moderate	0	6	2	0	0	8
4 Not much	0	3	2	1	0	6
5 Not at all	0	0	0	0	0	0
Total	4	11	5	2	0	22

5 DISCUSSION

The purpose of this study was to clarify the reflection process that causes positive change in student leadership behaviour. The results of a questionnaire survey conducted as part of the study were analysed. The survey was conducted in the middle of the course. The content of the study is about the change in leadership interpretation, the effect of accumulating data records in the e-portfolio used as a reflection tool, and the confidence in leadership and willingness to improve skills. First, the interpretation of leadership is considered. There are two characteristics of change. The first is from 'leadership can lead a team together and is exercised by one person who is better than others' to 'the ability that all team members need to demonstrate to achieve their goals'. The second is the shift from innate leadership skills to the interpretation that anyone can improve their skills through practice. These changes were brought about by learning through the literature on how

leadership should be at the start of the class and the content of lectures in face-to-face classes, as well as having hands-on experience of leadership in PBL activities. This change in interpretation seemed to lead to a change in the learner's self-consciousness and an attitude to look at the situation of others and the team. The weekly e-portfolio depicts an analysis of their leadership behaviour through reflection. Changes in leadership interpretation can be a factor that affects the reflection that leads to behavioural changes.

Next, the effect of accumulating learning record data in the e-portfolio is described. Learners checked the previous records at the time of reflection, compared them with the results of the time, discovered issues, and gradually learnt the learning process that leads to specific actions next time. By observing and monitoring their cognitive processes, students were able to accept and interpret the opinions of team members and adjust their behaviour. In addition, learners became more active and ambitious in PBL activities. This means that they had come to evaluate their own growth from the accumulated data, and as a result, their awareness of exerting leadership may have increased. However, subsequent behaviour depends on the attitude of self-evaluation and the viewpoint from which to judge. When trying to take on new actions, trusting in oneself to be successful can significantly contribute to motivation and achievement of goals [7]. The results of Questions 3 and 4 indicate that learners tended to have a strong desire to improve leadership.

However, some respondents did not have much sense of success when trying to exercise leadership. Keating et al. extracted three elements for the emergence of leadership behaviour: readiness – leadership self-efficacy; willingness – motivation for behaviour; and ability – leadership skills [8]. If self-efficacy influences the emergence of leadership, the breakthrough on the process of reflection that enhances self-efficacy may contribute to a positive change in leadership behaviour.

6 CONCLUSION

In this study, it was suggested that learners might change the interpretation of leadership and bring about positive behavioural changes by using e-portfolios and continuing to reflect on leadership behaviour. However, because responses to the questionnaire were voluntary, it is likely that the responding students tended to have a relatively high interest in leadership and a high willingness to acquire skills. On the other hand, the characteristics of students with such attributes are a clue to exploring the reflection process that causes positive behavioural changes in leadership behaviour. In the future, we will analyse the students' leadership behaviour frequency and reflection records concerning the prompts embedded in the e-portfolio from a quantitative and qualitative viewpoint. Furthermore, through interviews, we aim to clarify what the students were targeting in their reflection. For example, the question regarding whether students were reflecting on their internal emotion or external events was answered, in addition to how the reflection was implemented.

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AN INTERDISCIPLINARY EYE ON MATHEMATICS SERVICE TEACHING

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Conference Key Areas: *Mathematics in the engineering curriculum; Linking different disciplines both inside and outside engineering*
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ABSTRACT

The bachelor programmes at the University of Twente are designed as a series of thematic modules each centred on a project supported by disciplinary units. Ideally, a mathematics course included in a module is linked with other units and is related to the project, thereby encouraging interdisciplinary ways of thinking. Typically, first-year mathematics courses are largely decoupled from the projects as they are taught to many programmes simultaneously. To explicitly link the service mathematics to other fields, they include the option of contextualized and scaffolded exercises which we call “Cases”.

To achieve this explicit link, the design of any Case requires lecturers to communicate to align with both project and mathematical topics, as well as support in the roster. Most Cases were developed in the period 2014-2016. Meanwhile, both the mathematics courses and the modules have evolved, and some programmes dropped Cases altogether. These developments lead to the question of whether their design and use support the intended role and add value.

We evaluate each Case on alignment with the relevant mathematics course, alignment with the module and its design, highlighting Biomedical and Civil Engineering examples. We also determine whether the modules still incorporate it and, if not, the reason for exclusion. Preliminary data suggests that their design and use unevenly support the intended role of the Cases. Preliminary conclusions suggest certain Cases need a redesign, but also cause us to reflect on the existence of the need that the Cases are supposed to be meeting.

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1 INTRODUCTION

1.1 Mathematics in context

Engineers and engineering students use mathematics within their disciplines in many and various forms. Every university engineering programme includes mathematics prominently in the suite of courses offered to the students. Teaching mathematics as an isolated subject to engineering students runs the risk of engineering graduates having had a thorough mathematical education yet struggling to use that mathematics in the workplace [1]. Students need to see clearly the role mathematics plays in their disciplines and to develop not only mathematical competence but disciplinary-specific mathematical understanding. If they simply learn to apply some techniques, they might not see the limitations or necessary adaptations for a particular example.

In their 2013 report for the SEFI Mathematics Working Group, Alpers et el [2] stress that a competence-based approach to mathematics teaching must be integrated into engineering programmes to develop students' ability to apply mathematics in engineering contexts. They argue that students' motivation and engagement are encouraged through seeing mathematics in context and suggest projects or case studies as suitable vehicles for this contextualisation. Such case studies would provide "more demanding learning scenarios" (p. 59) than merely pointing out connections or providing isolated contextualised exercises. For instance, Härterich et al. [3] report on the success of three projects based firmly in engineering context requiring first-year students' skills at calculus and linear algebra, much as our Cases which we discuss here.

1.2 The Twente Educational Model and Cases

The Twente Educational Model (TOM, for Twents Onderwijs Model) structures the bachelor's programmes as a series of thematic modules broadly grounded in project-based learning [4]. In each module, students complete a group project and take part in disciplinary courses that support the project and one another to varying degrees. All technical first-year modules include mathematics courses in calculus and linear algebra; together these courses are termed the "mathematics line" which is taught to many programmes simultaneously. A key feature of TOM is interdisciplinary learning and teaching [5], avoiding the unfortunate silo effect that is prevalent in many higher education institutions, an effect to which mathematics is particularly vulnerable. To assist the linking of mathematics with other disciplinary courses and to distinguish it from the generic mathematics for each programme in a module the courses in the mathematics line can include so-called Cases.

A Case is a single problem or collection of related problems that contextualise mathematics in a context of relevance to the module. An example is the Civil Engineering module "Traffic and Transport" where the Case uses linear algebra to

model traffic flow across a road network. The basic premise is that all four first-year modules, each including a course of the mathematics line, will also include a Case as part of the teaching package and that the Case will be well-aligned with the module. Most of the Cases were designed in 2016 at the beginning of the institution-wide roll out of TOM. Meanwhile, modules and courses have evolved, staff has changed, and the use of Cases has been unproblematised and unmonitored.

We aim to answer the question “Are the Cases fulfilling their role?” by asking the subquestions “Does each module have a Case assigned and are they aligned?” and “How is their role perceived by the teachers?”.

2 METHODOLOGY

2.1 Repository review

A central server, accessible to all teaching staff, contains all the documentation related to the Cases. We accessed that server and took note of what Cases are present and looked for omissions. A full review of the Cases is underway. However, for brevity in this paper, we only make brief reference to the entirety of the Cases and instead focus closely on two programmes: Biomedical Engineering (BME) and Civil Engineering (CE).

2.2 Teachers’ evaluation of the Case

Each module has a team of lecturers who discuss educational issues together. For each team, one lecturer acts as module coordinator, typically keeping an overview, leading a course and the project. Each team also has a single responsible lecturer from the mathematics department as a contact person for the team, and sometimes also another leading the Case. We approached both persons for all four modules of BME and CE, module coordinator and Case lecturer. Of the mathematics lecturer leading the Case, we asked whether they had sufficient knowledge regarding the problem and whether they felt part of the module team. Based on their experiences, we wanted to know whether the students could achieve the Case, whether students learned something from the Case, and if the Case brought motivation to the students (the original argument for the Cases). Of the module coordinator, we asked their general impression and appreciation of the Cases as well as about any practical issues, since they were not involved in teaching the Case.

3 RESULTS

3.1 Review of all Cases

The overarching project of which this paper forms a part aims to assess all the Cases in the mathematics line for merit. The first step was to extract from the server mentioned above, all the Cases designed to date. Table 1 lists the Case topics for the departments of Advanced Technology and Electrical Engineering. These two

departments have a slightly different first-year mathematics curriculum to the other departments since their curriculum includes vector calculus. In contrast, the others encounter vector calculus in their second year of study. These two programmes are also unique in that they have chosen to abandon the Cases in their educational portfolio as they feel students see mathematics in context sufficiently without it. Table 2 lists the Case topics for the other programmes. Notably, some programmes do not have Cases available for all mathematics courses. A line of inquiry in our project will be to determine why, and whether this gap can be filled.

Table 1. Contexts of Cases by Programme and Course - inactive

	Calculus 1	Calculus 2	Linear Algebra	Vector Calculus
Advanced Technology	Complex pendulum (Mechanics)	Ideal gas laws (Thermodynamics)	Chemical equations (Fundamentals of Materials)	Drug costs (Dynamics)
Electrical Engineering	Complex pendulum (Intro to Elec Eng & Electronics)	(Electric circuits)	Electrical networks (Electronics)	Wave propagation and Maxwell's equations (Fields and Waves)

Module name in parentheses

Table 2. Contexts of Cases by Programme and Course - active

	Calculus 1A	Calculus 1B	Linear Algebra	Calculus 2
Business Information Technology	(Intro to BIT)	Retail inventory model (Software Systems)	Markov chains (Business Intelligence & IT)	(Data and Information)
Biomedical Technology	Branching blood vessels (Molecular Construction of Human Body)	Tumour growth (Microscopic Cancer Detection)	Least squares fit (Biomedical Measurement)	Bone inertial moment (Implant Design)
Civil Engineering	Moments of inertia (Intro to CE)	Error measurements (Water management)	Traffic flow (Traffic and Transport)	Bayes' Rule OR Capital growth (Designing Constructions)
Computer Science	Combinations (context-free) (Pearls of CS)	(Software Systems)	Data transmission (Network Systems)	(Data and Information)
Industrial Design	Piston models (Introduction to IDE)	Branching blood vessels (Ideation)	Force equilibrium in a truss	(Smart Products)

			(Realisation of Products)	
Mechanical Engineering	Force and material properties (Design and Manufacturing)	Ideal gas laws (Energy and Materials)	Force equilibrium in a truss (Energy and Sustainability)	Brayton gas turbine (Design and Mechanics)
Chemical Science and Engineering	Chemical reactions (Chemistry)	Heat exchanger (Process Technology)	Chemical equations (Materials)	Drug costs (Physical and Analytical Chemistry)
Industrial Engineering and Management	Company share price and advertising (Intro to IEM)	Retail inventory model (Operations Management)	Markov chains (Business Intelligence and IT)	Cobb Douglas production function (Supply Chain Management)

In almost all instances, looking at Table 2 above, it is clear that the topic of the Case appears to be aligned with the theme of the corresponding module. Of course, deeper understanding requires digging down into the nature of the Case and the teaching plan of the module. For this paper, we focus on Civil Engineering (CE) and Biomedical Engineering (BME) as two programmes which utilise Cases in all four modules.

3.2 Focus on Biomedical Engineering and Civil Engineering

The first module of BME concerns the design of a biomaterial as an aid for some body function. The courses involve Chemistry, Biochemistry and Anatomy. Initially Calculus 1A treated first-order differential equations too. The Case then dealt with Michaelis-Menten kinetics to study the effect of an enzyme complementing the treatise by Biochemistry. After a reshuffle of the content of the mathematics line, Calculus 1A no longer introduced differential equations but instead discussed the extreme value theorem for a single variable. The current Case discusses the branching of a blood vessel as a one-dimensional branching problem linking to Anatomy.

The second BME Module involves the courses Cell Biology and Microscopy with a project to detect cancerous tissue in a small sample. Calculus 1B always involved integration techniques which are easily related to solving differential equations. The Case discusses various population growth models, e.g. exponential, logistic or Gompertz, and relates the predicted outcome to observations of tumours made by a pathologist.

In the third quartile, BME students get acquainted with medical sensors to measure, for instance, diminished lung function in COPD. The courses teach Physiology, Network Analysis, Measurement Systems and programming with Matlab, while the Mathematics concerns Linear Algebra dealing with solving linear systems. These

systems are either underdetermined or square. Within the project, students get lots of data, so the Case considers the least-squares solution for overdetermined systems. The Case shows how to use Matlab for linear regression, and later on, students use the technique to analyse their data.

The first year finishes with a module centred around bones and implants. Students follow courses in Mechanics, Material Science and Imaging. The moment of inertia relates to a bones' strength, and X-rays are used to image fractures. Calculus 2 teaches multivariable calculus, e.g. multi-dimensional integration and different coordinate systems. The connection through the Case comes from computing the moment of inertia for bones with various geometries, e.g. the humerus with a triangular hollow shape for which students get a real X-ray image to estimate real-life parameters. As an example, we outline the content of this case and the classroom experience.

The Case starts with simple rectangular geometries (also discussed in the Mechanics course). We then introduce cylindrical shapes for hollow bones requiring to transform to polar coordinates. A particular bone (humerus) has a triangular shape. This shape turns out to be some 10% stronger than a plain cylindrical one. Students get an X-ray image of the humerus to obtain realistic parameters. Finally, they design an implant for this bone using material properties. Students work in groups of four and can ask support from lecturers and teaching assistants. Students familiarise themselves with the context starting with a few easy questions. Midway, the groups achieve the biggest mathematical hurdle. A few final questions follow for interpretation and application of the results. A typical session lasts 4 hours, sufficient for most groups to finish the Case. After grading (pass/fail and repair), the general solution strategy is discussed in a short feedback session.

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The first module of Civil Engineering (CE) concerns the redesign of the Enschede Station Concourse. The courses consist of Mathematics (Calculus 1A), Matlab, Professional Skills Development and three civil engineering courses: Structural Mechanics 1, Construction Materials and Fundamentals of Civil Engineering. Within the course, the students learn, among other things, how to design a structural system, to determine forces and deformation of beams and to calculate reaction forces and moments. The Case deals with using the method of region slicing to determining moments of inertia as single variable integrals. The Case does not draw on any of the mathematics content of Calculus 1A but instead uses school level mathematics to provide a mathematical context for moments of inertia.

The second module in CE focuses on the physical and policy aspects of water management, including the behaviour of different natural water systems and the effects of human interventions on these systems. The module units are Mathematics (Calculus 1B), Fluid Mechanics, Water, Policy Process and the project, which concerns the design of a dam and management of a reservoir in the Blue Nile in

Ethiopia. The Case concerns error, error propagation and least-squares approximations. The Case is not contextualised in the topic of water management but expands on an important topic related to approximation and data analysis.

Traffic and Transport is the third CE module in which the students learn basic theory from traffic engineering. The courses are Mathematics (Linear Algebra) and Transport Studies, both theory and project. The project concerns a substantial modification towards CO_2-neutral transportation in Enschede, taking into account accessibility and economics. The Case involves modelling traffic flow through a network with varying costs or weights as a system of linear equations.

The final module of the CE first-year programme and its central project relate to designing constructions. The courses within the module are Introduction Construction Project (project management, project organisation and project finance), Systems Engineering, the circular economy, Mechanics, Mathematics (multivariable calculus) and Professional Skills. There are two available Cases for this module. One Case relates to Bayes' rule on conditional probability, and the other Case is financial, looking at capital growth.

3.3 Views of teaching staff and module coordinators

Some of the mathematics lecturers leading the Case had been involved with its development. Others were replaced over the years. The latter expressed that they had sufficient general knowledge to deal with the Case; however, the context available during the development was not easily transferred to a new teacher. As a consequence, specific links to other parts of the module were lost. This disconnect came across in their feeling whether they felt part of the module team. If the teacher would be entirely new, (s)he was not yet embedded in the team, and continuity was lost. Discussions on educational development would be restarted every time.

We then discussed the experience of executing the Case. The Cases for Civil Engineering were certainly doable, i.e. completed within a session of four hours. The Cases for Biomedical Technology, on the other hand, turned out to be too extensive. The lecturers indicated that students mostly understood the idea of the Case, but their formula manipulation skills were overestimated, leaving the problems challenging to finish within the time allocated. While a few Cases taught a nice and relevant point, others did not achieve this link. We learned that one Case was cut short as students would use techniques from a different course to solve the Case, bypassing the pedagogical idea of the Case. Limited time for reflection is another hurdle to achieve a tangible link. In general, the mathematics teachers did not observe that the Cases raised enthusiasm for mathematics, and students mostly just did the Case because it was compulsory.

The module coordinators of Biomedical Technology were all convinced that Cases had added value, as it added to some of their courses or projects. We note that three out of four were involved with the development of the Case. For the fourth, there was a Case that linked well to a course initially, but it was replaced by something else because the contents of the mathematics line changed, and developing a better Case had a lower priority. For Civil Engineering, the module coordinators expressed their support for the aim of Cases and wish to keep the Cases, although they were unsure whether the current Case had added value for their module. For both BME and CE, it matters whether the Case takes place just before or after related practicals, and whether the relevant mathematics has been covered already in class.

A superficial perspective of the fit of the Case to the module was achieved by constructing Table 2. Speaking to the teachers of the Cases as well as the module coordinators provided two far more informative perspectives. The student perspective remains to be sought, both historical (through course evaluations) and current (through questionnaires or interviews)

4 SUMMARY AND CONCLUSION

The Cases were designed as contextualised and scaffolded exercises to explicitly link service mathematics courses with the disciplinary programmes. As time has passed since the current Cases were designed modules and mathematics courses have evolved and teaching staff have changed, prompting concern that the Cases may no longer be meeting the need for which they were designed. Returning to our original questions, we conclude that even though only some Cases fulfil their role, they are appreciated by the non-maths teachers. As with many interdisciplinary subjects, communication between teachers is essential for good Cases. In an observational study, Gast [6] concluded that professional development takes place within teams of lecturers, but this development would not happen automatically. We observed that staff changes in teams were detrimental for the added value of Cases, and that active support would be necessary to have sufficient discussion every year about the Case for each module.

At this early point in our project, we have learned valuable information about the CE and BME Cases, some extendable across all the Cases, some specific. We shall broaden our enquiry to include more departments and also to incorporate the student perspective. Cases have the potential to encourage students' motivation and engagement through seeing mathematics in context [2]. If there is a disconnect between Case and module, for whatever reason, it should be remedied as they provide an excellent educational material to tighten the link between maths and engineering.

ACKNOWLEDGMENTS
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CHALLENGE-BASED MODULAR ON-DEMAND DIGITAL EDUCATION: A PILOT

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ABSTRACT

A blueprint for challenge-based modular on-demand digital education (CMODE) was designed to: (a) provide students with a challenge-based learning environment that is learning-centered, rather than teaching-centered; (b) change the teacher's role from lecturing and knowledge providing to guiding, coaching and motivating; and (c) to provide on-campus contact hours that are complementary to an online learning environment. These goals of CMODE are formulated to increase student motivation for learning by providing them with additional freedom and responsibility, while aiming to exploit the potential advantages of challenge-based and blended learning. Based on this blueprint, a pilot program was created in 2019 for the bachelor Mechanical Engineering course 'Dynamics and Control of Mechanical Systems' at Eindhoven University of Technology. A practical challenge was created, which could be completed by handing in six deliverables. The online learning material consisted of six theory modules—aligned with the six challenge deliverables—that contained short weblectures, examples, quizzes and exercises. Finally, a new format for on-campus contact hours was implemented to improve complementarity with regards to the online learning environment.

Using a questionnaire and the student evaluations, in combination with the exam and challenge grades, we evaluated how CMODE affected students' learning and motivation. Preliminary results show better grades than the previous year, while students mention that they feel more motivated to stay on track with their learning.

1 INTRODUCTION

1.1 Motivation

Most educational programs are divided into learning lines that each exploit a classical course structure as depicted in Fig. 1 below. This type of learning line will typically start with several courses that students follow in predetermined order. To learn practical application of the knowledge, student will do a project at the end. One major drawback of this type of structure, is that it does not invite students to actively create their own knowledge or to engage in active learning [1]. Consequently, students will not always be able to see the practical relevance of all course topics, nor see the interrelatedness of all courses until they start with the end project.

To overcome this drawback, a blueprint was designed for challenge-based modular on-demand digital education (CMODE) that could, for example, exploit a sequential structure as depicted Fig. 1 below. The most important aspect of CMODE is a practical challenge that is provided to the students *at the start*. This challenge is divided into smaller tasks that can be completed by handing in a deliverable. Meanwhile, the knowledge required to complete each task is given in an online learning module.

The objective of CMODE is essentially to: (a) provide students with a challenge-based learning environment that is learning-centered, rather than content-centered; (b) change the teacher's role from lecturing and knowledge providing to guiding, coaching and motivating; and (c) to provide on-campus contact hours that are complementary to an online learning environment. These goals of CMODE are formulated to increase student motivation for learning by providing them with additional freedom and responsibility, while aiming to exploit the potential advantages of challenge-based and blended learning.

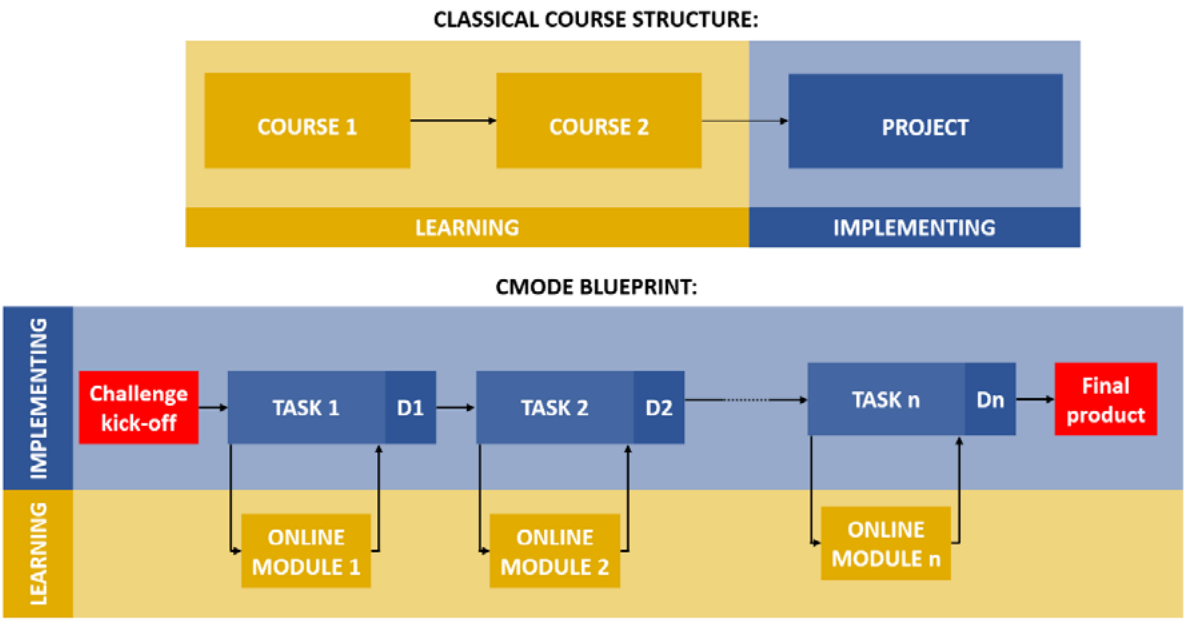

Fig. 1. An example of a classical course structure and the CMODE blueprint. Please note that sequential ordering is not a requirement for CMODE.

1.2 Modular education

In modular education for higher education, an entire educational program, or a subset of course(s) is split up into smaller modules that represent a strongly related set of learning objectives. Generally, upon completion of such a module, students receive credits that are representative of the size of the module. These modules are ideally independent and nonsequential, so that students can follow the modules in an order of their choice. Completion of *all* modules in an educational program results in regular certification of the program [2] [3]. Modularized education is thus a collection of bite-sized units of knowledge and skills, which offers students the possibility to choose their desired educational route and learning speed.

In general, it is argued that modular education provides students with a greater degree of autonomy, and greater responsibility for their own learning [2]. Additionally, it should also allow students greater flexibility to take on modules that belong to other educational programs; under the condition that they are still relevant for their major program. In this way, modular education allows students to develop more specific profiles of competences [4]. Most importantly, with modular education possibilities open up to provide students with education that is more tailored to their individual needs.

Modularization might be perceived as a difficult approach to implement. The coordination alone of all different modules and how they fit together is a daunting task. However, in current times where blended and online education become more popular, it seems that additional options to move towards modular education become available.

1.3 Student motivation to learn and online self-efficacy

Students' motivation highly influences students' learning outcomes [5]. In literature, mostly a distinction is made between intrinsic and extrinsic motivation, where intrinsic motivation is considered as having a more sustainable influence on learning outcomes. Research has shown that student autonomy on what and how to learn, can have positive effects on students' intrinsic motivation [5]. Online, on-demand education, and modular education provide them such autonomy and thus hopefully increases intrinsic motivation.

On the other hand, communicating with fellow students and instructors in online an online setting is different from communication in traditional on-campus offline education [6]. Some groups of students, such as shy students, favor communication in an online environment, whereas other groups of students might feel more disconnected from their educational program and fellow students; or they even feel overwhelmed by all online information [6]. Blended learning essentially offers the best of both worlds. In the next section we will present CMODE, which uses blended learning to provide students additional autonomy in their interactions with online subject matter. At the same time, a physical connection with their fellow students is maintained in on-campus lectures.

1.4 Context: course design

CMODE is developed within a multi-year project, with the intention of providing students with a more learning-centered environment, as opposed to the content-centered environments that are still the reality for many bachelor courses with large amounts ($n > 100$) of students [2] [7]. In this way, we aim to improve student engagement and intrinsic motivation, to increase the course grades and thus to have a positive effect on the learning outcomes.

For the first year, it is decided to consider a single course that is divided into several tasks and modules. In contrast with modular education, these modules should be completed in sequential order and students can only obtain credits by successfully completing the entire course. For this purpose, a redesign is considered for the bachelor Mechanical Engineering course 'Dynamics and Control of Mechanical Systems' (DCMS) at Eindhoven University of Technology. Due to historical reasons, this course consists of two separate parts: 'Dynamics' and 'Control' that are organized by different research groups. As a result, different course material is used for each part, the lectures are given by different teachers and the final exam is separated into two parts.

Before the academic year 2019-2020, the weblectures for 'Control' were a set of YouTube videos; for 'Dynamics', a set of short 5 to 7 minute videos—recorded in the on-campus recording studio—were used. During the on-campus lectures, the teachers of both parts lectured in a traditional manner (i.e. the teacher provides students with new information in a large lecture hall) and Kahoot quizzes were used to trigger student thinking and learning. The course grade was based on the students' performance during an interim Matlab test and a final multiple-choice

exam. In addition, bonus points could be gained by participating in the Kahoot quizzes.

In the evaluations of those years, it was often mentioned that the students regarded the weblectures as a repetition of the on-campus lectures (and vice versa), instead of being of added value. In addition, the students often did not recognize the relation between the 'Dynamics' and the 'Control' part of the course. Because these parts must be combined in the final project of the learning line—and in many real-world problems—students were often not able to directly apply the knowledge from DCMS in practice.

For the academic year 2019-2020, we used the CMODE blueprint to create a new course design for DCMS. A graphical depiction of this design is given in Fig. 2. The most important aspect of this, was the design of a challenge that consisted of six tasks. These tasks could be completed in sequential order by handing in the corresponding deliverable. In addition, the course material was distributed over six online learning modules that were directly aligned with the six tasks of the challenge. A Formative Assessment (FA) was created for each module, such that students could verify their understanding of the subject matter.

Modules 1–3 related to the 'Dynamics' part of the course, while modules 4–6 related to the 'Control' part. These were therefore not presented anymore as separate parts of the course, while additional effort was made in modules 3 and 4 to improve integration. Although the modules themselves were presented and taught in a sequential manner; within each module, students were completely free to decide in what order they would interact with the online material. Based on their previous knowledge and experience, students were self-directed towards the material of their choice.

The weblectures were not changed, although they adhere more to what is known about effective flipped classroom designs. The organization of the online part of the course together with the interactive lectures was based on the design as presented in [7]. To avoid repetition in the on-campus lectures, the focus was more on providing examples during the 'Dynamics' part, while for 'Control' the focus was more on providing intuition and explaining the idea behind the theory.

To support the students in the transition from a traditional educational format to CMODE, several safeguards were added to the course. Firstly, because students were not used to complete freedom and autonomy, a deadline was assigned to each challenge deliverable. Secondly, to avoid a situation where students would only focus on the challenge, they would receive a grade of 0 for any challenge deliverable if they did not pass the corresponding FA.

To ensure that these safeguards would not sacrifice too much freedom, the challenge deadlines were set relatively far in the future. Students could therefore, if they wanted, lag behind the on-campus lectures by two weeks. The FAs were available to the students until the evening before the final exam and they received an unlimited number of attempts.

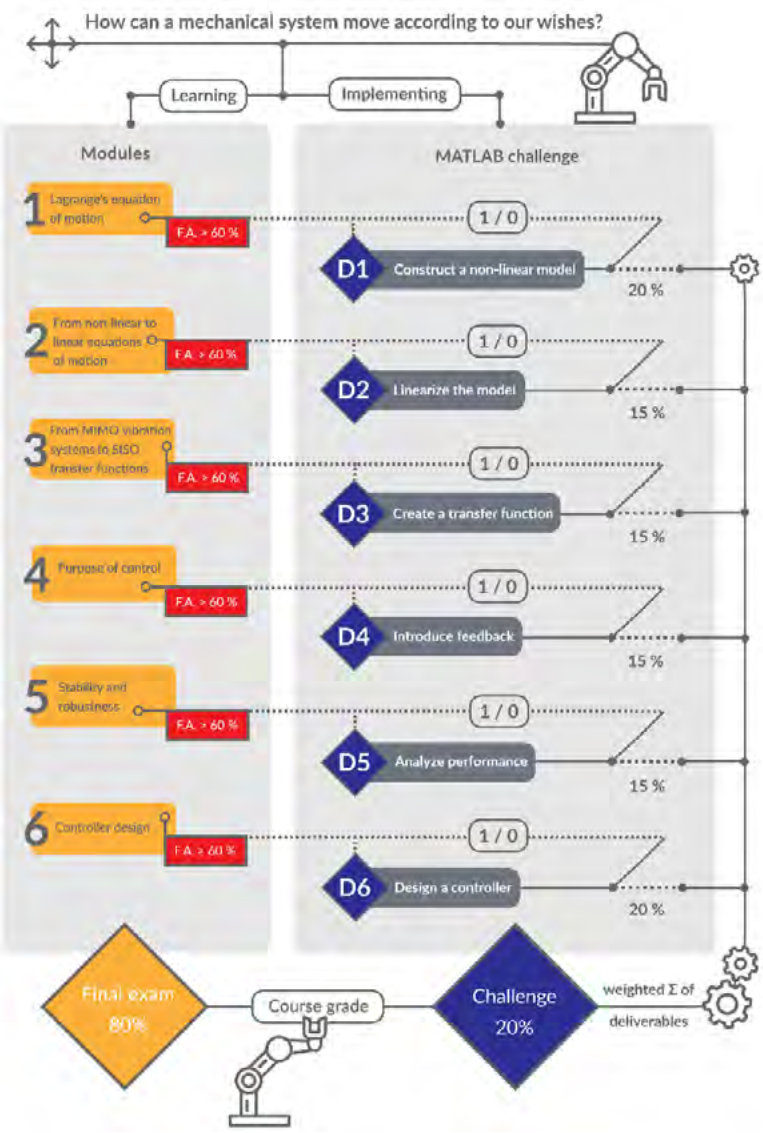

Fig. 2. The DCMS course design that was for 2019-2020

1.5 Problem statement and research question

In this paper, the focus lies mainly on the effect that CMODE has on student learning within the pilot course as described above. With the design of CMODE, we aim to help students interact more efficiently with the online environment and to increase their learning outcomes. Specifically, we are interested in the effects on (1) the students' motivation to learn; (2) student engagement in their own learning processes; and (3) student grades. The research question we therefore aim to answer with this study is:

How does a course redesign, based on the CMODE blueprint, affect student learning and motivation in the bachelor Mechanical Engineering course 'Dynamics and control of mechanical systems' at Eindhoven University of Technology?

2 METHOD

2.1 Participants

Participants in this study were the students of the course DCMS. Of all 369 students, the results on the final exam—which was made by 318 students—and the resit exam—which was made by 50 students—were collected. The 'Readiness for Online Learning Self-Efficacy' (ROLS) questionnaire was filled in by 230 students at $T = 0$ and by 71 students at $T = 1$; of these students, 32 students filled the questionnaire in on both occasions. For the purpose of this concept paper, we focus—for the results of the questionnaire—on the 32 students who filled in the questionnaire on both occasions. Finally, the course evaluation was filled in by 90 students.

2.2 Data collection

Student motivation to learn in this course was measured with an adapted version of the ROLS questionnaire constructed by [6]. In this version, the scale 'Computer/Internet Self-Efficacy' was left out, because this scale measures the students' self-efficacy regarding the use of programs like MS Word and Google. Students in this study were second year Bachelor students and were understood to have these skills, an assumption that the results in [6] supported. Students were asked to fill in this questionnaire online in the beginning of the introductory lecture ($T = 0$). Halfway through the course students were asked to fill it in again ($T = 1$). Student engagement and motivation was also measured using the student evaluations. After the course was finished, students received a link to the course evaluation and were requested to fill it in. This is an evaluation that is send out each year and we used the evaluations from 2019-2020. In addition, the students' final grades were collected from the challenge, the final exam and the resit exam.

2.3 Data analysis

MOTIVATION: After determining reliability of the ROLS questionnaire in this group (Cronbach's $\alpha = 0.799$), it was determined whether the scores for $T = 0$ and $T = 1$ differed significantly for the 32 students who filled in the questionnaire on both occasions with a paired samples t-test.
ENGAGEMENT & MOTIVATION: Student engagement and motivation were analyzed using the student evaluation data. A summary of the responses was made for the open questions that asked students what they liked and disliked about the course.
GRADES: Mean grades were calculated for both attempts of the final exam that were held the current year and the previous year. For the challenge, a mean grade was calculated for all students—that is, including the students that did not complete the challenge. Additionally, we analyzed whether there was a correlation between the challenge grade and exam grade using a scatter plot; together with a Gaussian distribution fit that was used to plot an 80% confidence ellipse.

3 RESULTS

MOTIVATION: The paired samples t-test showed that both measurements highly correlated for all subscales of the questionnaire ($\alpha \leq 0.01$). The means (as presented in Table 1) did, however, not differ significantly, with the lowest $\alpha = 0.121$.

Table 1. Means and standard deviations on the ROLS (5-point Likert scale)

	$T = 0$	$T = 1$
	M (*sd*)	**M (*sd*)**
Self-directed learning	3.33 (*.54*)	3.30 (*.71*)
Learner Control	3.40 (*.65*)	3.28 (*.68*)
Motivation for Learning	3.89 (*.55*)	3.71 (*.64*)
Online Communication self-efficacy	3.20 (*.79*)	3.11 (*.81*)

ENGAGEMENT & MOTIVATION: In the course evaluation, a large number of students mentioned that especially the challenge (and deliverables) helped them stay on track with their learning. Although the students would prefer a reduction in the workload, they observed that the additional work also helped them connect theory to practice; and thus to better understand the subject matter. The motivation to learn that appears from these evaluations is, however, not always intrinsic as is apparent in this student quote: “I did not like it but the deliverables really forced me to study and helped me to connect the theory to a practical application.”

GRADES: In 2019-2020, 258 students passed the course on the first exam attempt, while 28 additional students passed using the resit exam. As a result, 78% of the students passed the course in 2019-2020, which is higher than the 68% that was observed in 2018-2019.

In 2019-2020, the mean grade of the first and second attempt of the final exam together was 6.7 (out of 10), while the mean challenge grade was 7.5 (out of 10). This is an improvement with regards to 2018-2019, where the mean grade of the first and second attempt of the final exam together was 6.0 (out of 10). Note that there is no mean challenge grade available for 2018-2019, since it was implemented for the first time in 2019-2020.

A scatter plot of the exam grades and challenge grades in 2019-2020 is provided in figure Fig. 3. In addition, an 80% confidence ellipse is determined by fitting a two-dimensional Gaussian distribution to the data. From the orientation of this ellipse, we can conclude that there is a positive correlation between the challenge grade and exam grade.

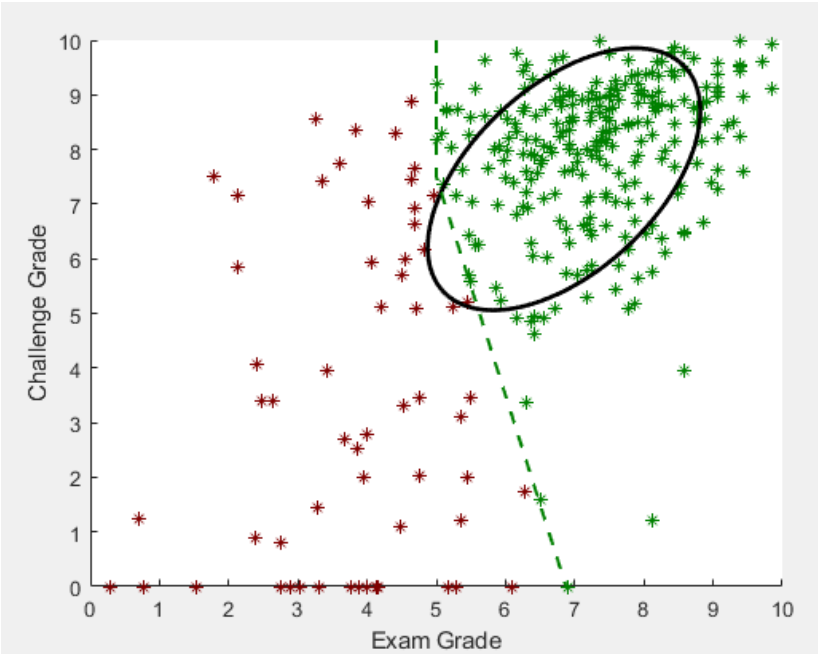

Fig. 3. A scatter plot of the exam grades and the challenge grades of each student, where a green color is used for students that passed the course and a red color otherwise. In addition, an 80% confidence ellipse is plotted.

4 SUMMARY

This study provided us with several insights. First, the preliminary results show no immediate increase in motivation to learn online, nor in the students' online self-efficacy. At the same time, students were also not demotivated by the new course setup, as was feared by several students who took the course in the previous year. Second, looking at the results from the student evaluations, CMODE seems to have a positive influence on student engagement. Especially the challenge (and deliverables) helped students to stay on track with their learning, while simultaneously fulfilling a motivating role. Last, both the mean challenge grade and the increased mean exam grade are a promising result. The positive correlation between the challenge and exam grade, in combination with the students' positive remarks regarding the challenge, leads us to believe that the challenge helps students to focus more efficiently on learning the subject matter; and thus to pass the exam with better results. This is, however, only one aspect of the pilot that deserves further investigation.

Other limitations in this study that will be addressed in the future are the ROLS questionnaire, which will be administered more times in the coming year (3 instead of 2 times). In addition, next year the survey questions will put more emphasis on typifying student motivation. We also want to interview students about their perceptions of the course in relation to other 'traditional' courses. Finally, we aim to collect data to determine whether CMODE prepares students for future courses, such as the aforementioned final project of the learning line.

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TOWARDS MULTIDISCIPLINARY ENGINEERING CURRICULUM DESIGN: A PILOT STUDY TO TEACH CONTROL EDUCATION IN MECHANICAL ENGINEERING WITH MATLAB/SIMULINK AND ARDUINO

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Conference Key Areas: *Interdisciplinary engineering education, Challenge based education, Maker projects.*
Keywords: *Multidisciplinary curriculum, project-based learning, mechanical engineering, control education*

ABSTRACT

Current challenges in engineering curriculum design, face the necessity of a multidisciplinary approach due to the increasing complexity of engineering problems. Students need to be exposed to a multidisciplinary environment and, on the other hand, it is necessary to ensure the teaching of all the fundamentals of each engineering within the respective curriculum.
As an example, the contribution of automatic control to engineering has become a recognized pillar among the fundamental disciplines in engineering education. However, the instructors teaching control courses to students belonging to other engineering degrees than automation, must design a syllabus providing the right balance between fundamental theory and practical applications. To overcome these problems, we propose a novel approach consisting in the introduction of hands-on

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activities based on an Arduino engineering kit to teach control systems to mechanical engineering students.
The novelty of this pilot study consists of bringing such a practical approach to the laboratory classes of robotics and mechatronics within the mechanical engineering curriculum involving also basic concepts of electronics and data acquisition and processign throught the interaction with sensors and actuators as well as programming skills to implement the control alogorithms on the Arduino device.
This experience proved to be successful in helping students to maximize progress and build an effective comprehension of crucial engineering topics. It also showed that the hardware is appropriate to demonstrate and apply core learning principles. Moreover, it can be considered as a benchmark with potential effectiveness also in other courses and curricula. By realizing this approach, we envision that engineering education will be able to build important skills necessary to break down the walls between disciplines, enable cross-collaboration, produce well-rounded students, and increase employability opportunities.

1 INTRODUCTION

The more industry grows and evolves, the more professional engineers must develop working skills and knowledge beyond their original discipline due to the requirements of their employment. The risk is that most engineering graduates, although technically competent, do not have enough practical nor complementary professional skills required for working successfully in the workplace. The solution to address this issue needs to consider rethinking engineering curricula design as to increase their multidisciplinary. However, a common understanding on how to effectively do so has not been reached yet. Successful strategies may be identified in the adoption of maker projects, or the use of professional tools within laboratory activities of each curriculum.
As a pilot study to demonstrate this statement, we shall consider teaching of control theory in a mechanical engineering curriculum that, despite it has been pervading almost all subjects of higher learning, it is usually only available to students at the end of the undergraduate education and, most importantly, it typically stops at a theoretical level. Consequently, control theory practical applications remain unfamiliar to mechanical engineering students, who lack of a general comprehension of how control systems permeate a great variety of aspects regarding mechanical systems. This problem may find its roots in early tendencies in education promoting training approaches aimed at preparing high specialized students with deep competences but focused on a narrow spectrum of topics, in opposition to the current view supporting the need of interdisciplinary professional profiles, able to adapt to a wide scenario of situations and able to solve a variety of issues not strictly related to their specific area of expertise. Moreover, building hands-on experience about control theory problems in study programs falling outside automation engineering is usually overshadowed by the need to include core-teachings of those curricula. It is also worth considering that an effective laboratory of control theory builds on the foundations of statics and dynamics, circuit theory, signal processing

and programming coursework. Providing such a practical experience is often a great aid for teaching difficult concepts, but, on the other hand, forcing a hands-on approach can distract students from theoretical learning if they are unprepared [1]. This might be the case of undergraduate mechanical engineering students, who have a limited educational experience in control theory and are typically lacking in one or more of the above-mentioned foundations.
To address this need of a successful and feasible laboratory activity, aimed at teaching control theory at mechanical engineering students, this paper proposes a case study in which a project-based learning approach [2], [3], consisting on the use of maker projects, was applied to a conventional laboratory of robotics and mechatronics of the mechanical engineering curriculum at the University of Bologna, Italy. Specifically, this approach aimed at filling the gap between the competences in hardware development, widely taught in the mechanical engineering curriculum, and the actual lack of confidence with software development for mechanical system control, which is crucial to form students with a comprehensive perspective. Project-based learning consists of a model that organizes learning around projects grounded in the theoretical background of constructivism, a learning theory that perceives learning as a process of constructing knowledge based on experience [4]. In project-based learning, students are engaged in diverse components of problem solving, interdisciplinary curriculum, open-ended questions, hands-on activities, group work, and interactive group activities [5], [6].
We investigated to what extent a kit developed by Arduino in collaboration with MathWorks, can be successfully used in a project-based module, to enable mechanical engineering students grasping fundamental control principles [7], [8]. Our idea is that such an approach allows for students or student teams to design smart solutions, experience input-output systems with data gathering, decision rules and output commands. Also, it may encourage students to increase their awareness and perception of control topics, improving their engagement and the learning itself.

2 METHODOLOGY

2.1 Experimental set-up

The project was based on a kit, developed by Arduino in partnership with MathWorks, aimed at providing a hands-on educational approach for students. The idea behind this kit is to enable college students and educators to incorporate core engineering concepts into their Arduino projects with the support of MATLAB and Simulink programming, thanks to industry-standard tools for algorithm development, system modeling, simulation and robotics, all of which will be required in their future careers [9].
Arduino is an open-source hardware, software, and content platform with a worldwide community of over 30 million active users. It has powered thousands of projects over the years, from everyday objects to complex scientific instruments. MATLAB is a programming platform specifically designed for engineering and scientific computing. The MATLAB Support Package for Arduino enables the user to

communicate with Arduino hardware directly in MATLAB. Users can interactively read data from a variety of sensors and peripheral devices, process raw data into meaningful values, and actuate external devices. Simulink is a block diagram environment for modeling and simulating dynamic systems, which supports developing algorithms that can be embedded into Arduino and other hardware. The Simulink Support Package for Arduino extends Simulink with blocks for configuring Arduino sensors, as well as reading and writing data from them. After creating a Simulink model, users can run the simulation and interactively tune algorithm parameters in order to meet the expected result. Through automatic code generation, the Arduino support package removes the need to write C or C++ code. That also means that users don't need to compile and build an application for it to run. Users can then download the completed algorithm for stand-alone execution on an Arduino device.
The specific application proposed in this project consisted in assembling a self-balancing motorcycle, which can maneuver on its own on various terrains and remain upright using a flywheel for balance (see Figure1 (a) and (b)). The Arduino Engineering Kit includes step-by-step instructions and lessons, featuring a short introduction, a getting-started guide for the tools that will be used, a concepts section, and finally the projects themselves. The robot is controlled by a series of Arduino boards (MKR1000, MKR Motor Shield, MKR IMU Shield (see Figure1 (c)), several customized parts, and a complete set of electrical and mechanical components (a DC motor with encoder, a standard micro servo, a hall sensor module, an ultrasonic sensor and a speedometer).

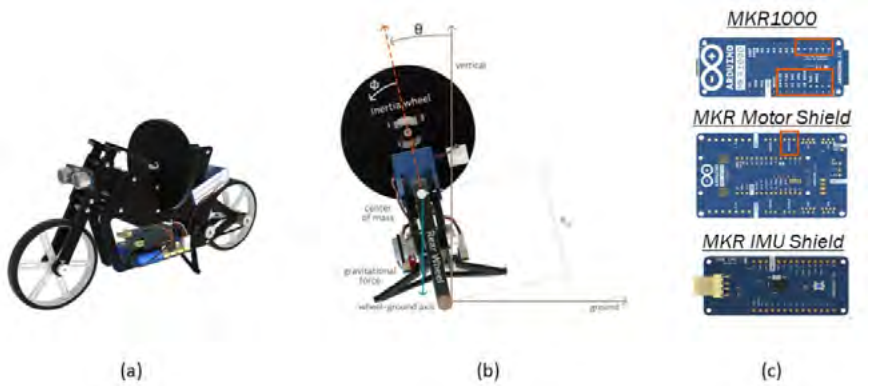

Figure 1: a) the self-balancing motorcycle of the Arduino engineering kit; b) Study of vehicles kinematics' and dynamics in order to design a model; c) The set of the three Arduino boards (MKR1000, MKR Motor Shield, MKR IMU Shield) controlling the robot

2.2 Learning activity

Students were requested to create models for the control of the hardware components and to design and run a hardware-in-the-loop simulation to tune and validate the controller's parameters in order to improve the developed algorithms. Instructions to students were also to program the control algorithm in MATLAB and Simulink, which can easily interface with Arduino, thanks to the already available support packages.

The laboratory experience with such as Arduino engineering kit consisted in two phases: in a first, step students had to study the vehicles kinematics and dynamics in order to design its model (see Figure 1) and, in a second phase, they had to implement such model in Simulink and simultaneously assemble the hardware components. The two phases continuously interchanged during the development process, as students chose to follow a step by step approach in which they evaluated the implemented changes in the controller by simulating them in Simulink.

3 RESULTS

All students successfully completed the project-based module, and reported that this activity certainly facilitated a better understanding of the theoretical concepts of control theory that were covered along the project. Also, they reported Simulink to be user-friendly and flexible (also for real-time applications), oriented to components safety and effective in controlling the inertia wheel. They also identified some future applications and developments, specifically consisting in the implementation of an algorithm for the self-calibration of the IMU in real time, the development of an algorithm for pre-defined trajectories and possible improvements in the algorithm for obstacles avoidance.
Overall, what students learned during this hands-on activity, can be summarized as follows:

- Modelling and simulation of the the dynamic system's behavior in Simulink (Figure 2)
- Application of custom algorithms for complex math operations, and PID control
- Incorporation of logic-based algorithms that define system behavior for different states (e.g. move forward, turn, stop)
- Building and running a working Arduino application from a Simulink model; connecting MATLAB and Simulink to the Arduino MKR1000 and reading/writing of data from connected sensors (encoders, IMU, hall sensor) and actuators (DC motors, servo motor); tuning and optimizing Simulink model parameters as the application is running on Arduino
- Analyzing and visualizing data from Arduino

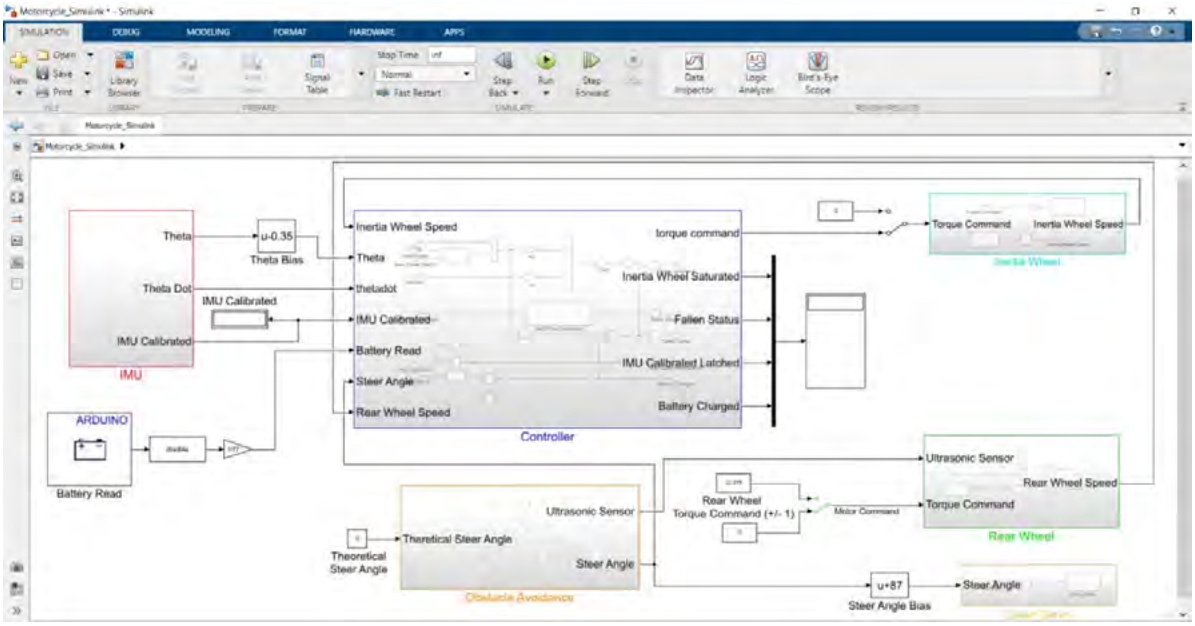

Figure 2: Overview of the Simulink model controlling the self-balancing motorcycle. Model subsystems comprise, from left to right, the IMU capturing the inclination angle (red), the controller generating the torque command (blu), the obstacle avoidance algorithm

The case study presented here provides evidence of effectiveness and feasibility of applying a project-based learning approach to teach control theory in the laboratory of robotics and mechatronics in a mechanical engineering course. This approach, based on the Arduino Engineering Kit programmed with MATLAB/Simulink, proved to be suitable for future uses in additional modules, as it kept students motivated and engaged and, most importantly, it appeared to be highly effective in delivering complex theoretical concepts, otherwise difficult to grasp.

4 CONCLUSION

An essential aspect to consider in the design of engineering curricula is that at the end of the course students preparation meets industry demands. Indeed, the skills and knowledge that engineering students acquire during their studies play an important role in their employability and ultimately their success. As a matter of fact, employers are finding it progressively more difficult to employ engineering graduates who can be productive and master design tasks, methodologies and tools with minimal retraining. To maintain a healthy flow of new graduates into industry, a systematic approach is required to bridge the gap between employer expectations and graduates' skills. In order to fill the gap between the necessity of engineering curricula to teach multidisciplinary and practical skills, and the need to identifying the still missing best practices to reach these objectives, we proposed the implementation of laboratory activities based on maker projects to teach control in mechanical engineering. From this study it emerged how the use of such cutting-edge Arduino-based project allowed students to easily learn fundamental engineering concepts, key aspects of mechatronics, such as MATLAB and Simulink programming. Millions of engineers and scientists in various industries and academia

use MATLAB for a range of applications, including deep learning and machine learning, signal processing and communications, image and video processing, control systems, and many more. Also, in this specific application, students could exploit the functionality of MATLAB/Simulink of being a high-level language, thanks to which users can see results immediately from I/O instructions without having to compile code and thus, allowing them to just focus on the engineering modelling and design. Another aspect to consider is that an effective control education course is yet to be defined, and successful study plans are still under investigation [10]. What emerged to be clear, however, is the need to foster the acquisition of appropriate technical skills by ensuring a combination of fundamental theory and practical applications, overcoming the constrains imposed by the very limited time span that needs to include lectures, labs and exercises [11].

We here exploited the positive effect of practical experiences on the learning process, well established since the early theories on experiential learning [12] by implementing hands on activities based on a Arduino engineering kit programmed with MATLAB and Simulink to teach control systems to mechanical engineering students. The novelty of this pilot study consisted in bringing such a practical learning approach to the laboratory classes of robotics and mechatronics within the mechanical engineering curriculum, which up to now was only limited to a theoretical overview of control topics.

This experience proved to be successful in helping students to maximize progresses and build an effective comprehension of crucial topics otherwise of difficult understanding. Indeed, students were also exposed and needed to solve also basic problems concerning electronics and data acquisition and processign throught the interaction with sensors and actuators as well as programming aspects to implement the control alogorithms on the Arduino device.

It also emerged how hardware is appropriate to demonstrate and apply core learning principles.

Such proposal is to be considered as a benchmark with high scalability potential and we envision it might have a similar feasibility and effectiveness also in other engineering courses, not only for advanced students, but also during the early years at university.

In fact, it may substantially help teaching of introductory courses that up to date still challenges academics trying to identify what resources to use, what topics to include, how to assess or teach and, more specifically, what examples would constitute expected levels of performance and comprehension. Indeed, this case study provides project description, simulation software, and code so that academics can quickly and easily include them in their own teaching. By realizing this approach we envision that engineering education will be able to build important skills necessary to break down the walls between disciplines, enable cross-collaboration, produce well-rounded students, and increase employability opportunities.

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STUDENTS' MENTAL CONSTRUCTIONS OF CONCEPTS IN VECTOR CALCULUS: INSIGHTS FROM TWO UNIVERSITIES

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Conference Key Areas: *Mathematics in the Engineering Curriculum*
Keywords: *Vector calculus, APOS theory, mental constructions, student success*

ABSTRACT

Student success in Mathematics is a global priority. Mathematics is a fundamental part of engineering programs in higher education, necessary for application in further engineering studies and yet often becomes a stumbling block for engineering students. Concerningly, even successful students frequently exhibit weak understanding of key mathematical concepts. The vector calculus course is known to be particularly challenging for students.

While much research has been done into students' constructions of core concepts at school level, less has been done on advanced mathematical topics such as vector calculus, yet this important insight has the potential to impact curriculum and pedagogy and to inform relevant support. This research conducted at the University of Twente, the Netherlands and the University of Cape Town, South Africa will use the constructivist APOS (Action-Process-Object-Schema) Theory to explore how students mentally construct concepts such as partial derivatives, directional derivatives and double integrals. APOS theory is based on the hypotheses that individuals construct mental actions, processes, and objects and organise them in schemas to solve mathematical problems.

In this exploratory case study we attempt to explore and understand how our students understand the limits of integration of double integrals, informing the design of our teaching of vector calculus to improve students' understanding and ultimately increase success. Students will participate in an assessment, complete a survey and participate in individual interviews. APOS Theory can be used directly in the analysis of data. Although initially intended we were unable to use this opportunity to compare the mental constructions of the cohorts from the two different universities and it will be assigned to future research.

1 INTRODUCTION

Mathematics is fundamental to the study of engineering courses and has an important bearing on the success of engineering students. There are increasing concerns about the transition from studying mathematics at high school to university and many research studies focus on “students' preparedness” to study higher education mathematics. Engineering programs are known to be very selective and even for those students who meet the mathematics requirements for engineering enrolment, mathematics problems still persist and the lack of mathematical preparedness and mathematical proficiency remain a barrier to the study of engineering [1].

Although there are various problems associated with this transition from high school to university it is said that the procedural approach to learning mathematics in school particularly aggravates that transition. Conceptual understanding is commonly known as deep level understanding of underlying concepts in mathematics and their relationships with each other. Recent research focus has been on students' understanding of mathematics at undergraduate level and a call for learning approaches in mathematics to change from procedural to conceptual and for teaching for conceptual understanding in mathematics. It is asserted that mathematics courses whilst providing necessary skills for the study of other courses should also foster cognitive and metacognitive abilities allowing students to be lifelong learners and creative and critical problem solvers.

Studies have shown that in some cases there is a disconnect in the teaching and learning dynamic between mathematics taught and what students learn. This occurs for various reasons, some of which from the teaching end involve an underestimation of the difficulty of the concept for the student, an assumption that students have the prerequisite knowledge, and an unintentional omission of knowledge vital to students understanding the concept. Research into how students learn and understand mathematics allows for a better articulation of teaching practice and an alignment between what is taught and what students learn. In this research we recognise that in accordance with the philosophy of constructivism a better facilitation of student meaning making in mathematics is central to their learning.

1.1 Background

Calculus is central to engineering. Calculus, as the mathematics of change and motion, is indispensable in any form of mathematical modelling. Ordinary and partial differential equations, multiple integrals, curl of a vector field, Stokes’ and Gauss’s Theorems are all found in any introductory textbook of engineering mathematics.

Research suggests that vector calculus is one of the important and difficult courses in undergraduate mathematics studies, challenging for any student. Certain issues contribute to this challenge such as difficulty with imaging and sketching in three

dimensions, a lack of problem-solving skills, students' beliefs and students' learning styles. Visualisation and the many conceptual challenges around continuity and differentiability in these contexts challenge all students. Another suggestion for students' difficulty is that the course demands of students that they absorb complex and new ideas in a limited time. It is our experience that students are already contending with an overload of other courses in their respective engineering qualifications. [2:23] point out that "the shift from single variable to multivariate calculus is more than simply a matter of the symbolic demand of calculus with more variables".

The study of functions of two variables forms an important foundation to the study of engineering. The double integral is frequently used in engineering from finding areas, volumes, areas of surfaces to computing mass, electric charge, work, centre of mass and moments of inertia to name some of the many applications.

Our focus in this research on double integrals is driven by the fact that research in this area is not extensively explored. Research shows that students experience difficulties with double integrals especially with determining the limits of integration and changing of order of integration [3]. In the research reported on here we analyse students' mental constructions of the limits of integration of double integrals with the main objective to provide evidence to inform the teaching and learning of double integrals. The authors acknowledge that whilst there are various factors which impact student understanding this research focuses only on the cognitive facet of student understanding.

1.2 **Theoretical Framework**

This study uses APOS (Action-Process-Object-Schema) theory to analyse the mental constructions of students taking a test on double integrals. Learning takes place in four stages when students construct mathematical concepts. The four stages are: action, process, object and schema. Actions are a transformation of mathematical objects when students follow some explicit algorithm to perform the operation and this is perceived by the student as externally driven, for example something they would have been taught or from memory. This is a step by step procedure where one step cues the next. At this point students are not able to anticipate or skip any steps. Upon repeating the action and reflection on the action the student internalises the action as a process. At this stage the student has gained control over the actions. Upon performing actions on processes, it is said that students have encapsulated the process and constructed a cognitive object. "In many mathematical objects it may be necessary to de-encapsulate an object and work with the process from which it came" [4]. A schema for a mathematical concept is a student's response when presented with a mathematical problem situation and is based on their framework which is built from a collection of the students' actions,

processes, objects and other schema linking the mathematical concept to general principles.

Genetic Decomposition (GD) or model of cognition of the mathematical concept describes a possible and not necessarily unique way in which a student constructs a mathematical concept in terms of the mental constructions in the framework of APOS theory. This description of specific mental constructions made by the student to develop an understanding of the concept is for design and analysis of teaching and learning.

2 METHODOLOGY

In this section we give the context, research design, research questions and propose a genetic decomposition for finding the limits of double integrals.

2.1 Context

Two cohorts of students were intended to contribute data for this project. The University of Twente participants were the electrical engineering and advanced technology students in their first year of study in 2019/2020 and for the University of Cape Town, the second-year engineering students in 2020. The project will investigate students' understanding of a range of concepts in multivariable and vector calculus, including but not limited to directional derivatives, double integrals, divergence and curl.

For the purposes of this paper we report on a pilot study that will inform the project going forward. Unfortunately, the global coronavirus crisis and ensuing constraints on our institutions resulted in data being gathered from 97 students from the University of Twente only. In essence this paper can be seen as a first step towards realising our vision of the project, that of understanding students' mental constructions of vector calculus concepts to inform our teaching. In this concept paper we will focus on students' understanding of the limits of integration for double integrals. We shall present the analysis of that data as an indication of the expectation from the project.

2.2 Research Design

For each of the multivariable and vector calculus concepts of interest in the study we shall postulate a genetic decomposition (GD). A GD is a detailed description of a set of mental constructions a student will use in developing an understanding of the concept under study. These mental constructions are called actions, processes, objects and schemas and play a role in the development of an understanding of the concept. Our GD for determining the limits of integration for double integrals is informed by past research, literature and the researchers' mathematical knowledge and teaching experience. Arriving at a genetic decomposition which describes the

students' actual mental constructions and informs the teaching of the mathematical concept requires many cycles of research involving GD posing or refining, classroom activities and data gathering [4].

This research describes only the first cycle in this process. Students' understanding of the concepts will be analysed through the lens of APOS theory using data from assessment and, where possible, interviews. The data presented in this paper were drawn from a test taken by the participants from the University of Twente. The tests were graded, and the responses analysed using APOS Theory by one of the authors. The grading and the analysis were also undertaken by the other author for consensus.

The two authors are the lecturers and graders for the applicable mathematics courses and hence have access to students' test responses. To include students' written work in a publication ethics approval will be applied for. For this report on the pilot study no direct examples of student work will be presented.

The limitations of this research study as a consequence of the global pandemic and lockdown was that we were unable to further probe students' mental constructions of the vector calculus concept during interviews and to compare the mental constructions of the cohorts from the two different universities.

2.3 **Research Questions**

"What are Vector Calculus students' visual and analytic understanding of vector calculus concepts?
This paper contributes to answering the sub question: "What are Vector Calculus students' visual and analytic understanding of the limits of integration for double integrals?"

2.4 **Genetic Decomposition for Double Integrals**

In this section we start with prerequisite knowledge that students will need before performing the mathematical task and propose a genetic decomposition of finding the limits of integration of double integrals.

Prerequisite knowledge:

- Recall of and understanding of notation encountered previously in differential calculus- e.g dx - with respect to the variable x, dy - with respect to y.
- Techniques previously used in single integration
- The integrals of polynomial, trigonometric, inverse trigonometric, exponential and natural logarithmic functions;
- Determining limits for the definite integral and basic algebraic operations
- Double integrals over rectangular regions

Actions: These are mechanical procedures which lack meaningful internal relations to other mathematical ideas. At this stage there is a transformation of a mathematical object by applying a rigid step by step algorithm which is perceived as externally driven. A student evaluates a double integral by computing an iterated integral over a region which is either a:
Type 1 region: integration is first with respect to y, in the vertical direction (bottom to top) and then with respect to x by seeing the region between two functions of x and two vertical lines respectively, or a
Type 2 region: integration is first with respect to x, in the horizontal direction (left to right) and then with respect to y by seeing the region between two functions of y and two horizontal lines respectively
At this stage the student has an action understanding of setting up a double integral with limits of integration.

Process: Students when repeating actions and reflecting upon actions will internalize them. Specifically, the student can imagine performing the transformation without having to execute each step explicitly, seeing a step by step algorithm as no longer necessary. When faced with the iterated integral where the integration order is $dydx$, integration with respect to y is required first and then followed by integration with respect to x, students will no longer need to identify the region as type 1. Students will realise that integration will take place vertically first followed by horizontally. Now students will identify the function of x which lies above the region i.e the region is bounded above by that function and the function of x which lies below the region i.e the region is bounded below by the function for values of x in an interval (left to right). Similarly, students will proceed when the iterated integral requires integrating $dxdy$, first with respect to x and then with respect to y.

Object: When a student applies and can imagine applying such transformations then it is said that the process is encapsulated into a cognitive object. The student with an object conception of the mathematical operation may, unprompted and needing no further instructions, recognise the applicability of the mathematical operation in a given problem situation. For example, the student understands that for double integrals we are sweeping the area under volume. Realising that taking slices of the volume into two dimensional slices of area, computing that area of each slice and summing over all areas of slices will give the volume as a whole.
In our particular test example, a student would when confronted with setting up an iterated integral in the order $dydx$ will then “de-encapsulate” the object to the process that it came from and apply it to a particular situation. For example, here a student will note that when looking at the order of integration firstly with respect to y and then with respect to x. Taking slices of the volume yield the same lower boundary function for the region in question but not the same upper boundary function. That would require thinking of the region as a sum of two regions over which integration will take place and hence the double integral in question will be

reflected as a sum of two double integrals each of which is bounded by the same function above and below.

Schema: This is a coherent collection of actions, processes and objects and other previously constructed schemas.

3 RESULTS AND DISCUSSION

Two items from a mathematics test taken by 97 electrical engineering students are analysed here. Focus is on the students who interpreted the task incorrectly. It must be noted that this is an initial analysis as further probing by interviewing students to obtain a clearer understanding of students' mental constructions could not take place.

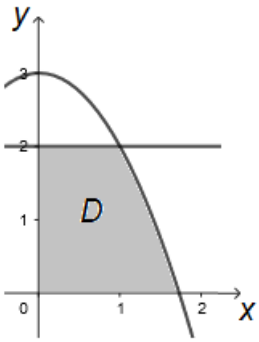

Fig. 1. Test item on double integral

The density of lamina *D* at point (x, y) is twice the distance from the point to the *y*-axis. Write down (<u>but do not evaluate</u>) an iterated double integral to represent the mass of lamina *D* shown below. Do this first in the order $dxdy$ and then in the order $dydx$. *D* is bounded by $x = 0$, $y = 0$, $y = 2$ and $y = 3 - x^2$.

3.1 Double integral APOS analysis, UT electrical engineering

Given the context of the test question item 1 required students to set up an iterated integral for integration in the direction $dxdy$. The correct interpretation of item 1 would result in integral 1 as shown below:

Integral 1: $\int_0^2 \int_0^{\sqrt{3-y}} \sigma dx\, dy$ where σ is the density of the lamina.

Student Responses:

Four students responded with: $\int_0^2 \int_0^{3-x^2} \sigma dx\, dy$

Students displayed the action stage and were able to determine the curves that make left and right boundaries of the region. They recognised that integration firstly was with respect to x and this formed the 'nested' integral and that the outer integral limits go from $y = 0$ to $y = 2$. However they failed to recognise that the boundary

curves are functions of y and not x. It may be correct to suggest that the students are in the action stage and have not made the transformation to the process stage yet.

Two students responded with: $\int_0^2 \int_0^{\sqrt{y-3}} \sigma dx\, dy$

Here students having successfully recognised the order of integration have proceeded to find $x = f(y)$ for boundary curves, thus showing that a process stage has been reached. However, an algebraic error leads the student to an upper limit of $x = \sqrt{y-3}$ and the student is unable to reflect that $y \leq 3$ for the region under consideration. The object stage has not been reached since a real understanding of limits as a description of the region should have flagged the domain of the upper bound function for x.

One student responded with: $\int_0^2 \int_{\sqrt{3-y}}^1 \sigma dx\, dy$

Here the student changes the region of integration and integrates from right to left on the inner integral. There is a recognition that the inner limits of integration need to be functions of y, yet the visual interpretation is not present. It may be said that the student is not following an algorithmic approach here and cannot be said to have reached the action stage.

One student responded with: $\int_0^3 \int_0^2 \sigma dx\, dy$

This student proceeds as if the region is a rectangular one. Therefore, the student does not show knowledge of an algorithm in terms of how to proceed. It can be said that this student has not reached the action stage. In fact, prerequisite knowledge of integration is lacking.

Given the context of the test question, item 2 required students to set up an iterated integral for integration in the direction $dydx$. The correct interpretation of item 2 would result in integral 2 as shown below:

Integral 2 : $\int_0^2 \int_0^{\sqrt{3-y}} \sigma dx\, dy = \int_0^1 \int_0^2 \sigma dy\, dx + \int_1^{\sqrt{3}} \int_0^{3-x^2} \sigma dy\, dx$ where σ is the density of the lamina.

Student Responses:

Eighteen students responded with: $\int_0^{\sqrt{3}} \int_0^{3-x^2} \sigma dy\, dx$

These students are considering the entire area as if it were bounded by the same function above, not realising that $0 \leq y \leq 3 - x^2$ is not true for the entire interval, i.e $x \in [0,3]$. Students have merely followed steps here without acknowledging visually the shape of the area which in this case warrants that the area be represented as a sum of two integrals. There appears to be an action stage reached but certainly no process stage can be observed.

Three students responded with: $\int_0^1 \int_0^2 \sigma dy\, dx + \int_1^2 \int_0^{3-x^2} \sigma dy\, dx$

Students are at the process stage where the shape of the region is recognised to give rise to the sum of two integrals. There is however a failure to recognise that $x =$

2 is clearly outside the region under consideration. It is clear from the diagram given in the test question that x does not extend to 2.

One student responded with: $\int_0^1 \int_0^2 \sigma dy\, dx + \int_1^{\sqrt{3}} \int_0^{\sqrt{y}} \sigma dy\, dx$

This student has recognised that the region should be split in two regions and integrals evaluated over each of these regions should be summed. The student seems to be at the process stage as the student reads bounds bottom to top, however does not show an understanding that the limits of the inner integral are functions of x, which is an indication that the student is actually at the action stage.

One student responded with: $\int_0^1 \int_0^2 \sigma dy\, dx + \int_1^{\sqrt{3}} \int_0^{\sqrt{3-y^2}} \sigma dy\, dx$

The actions of "read region bottom to top" and "find bounding curves" and "bounding curves of inner integrals must be $y = f(x)$" when the nested integral calls for integration with respect to y become internalised as a process that results in an object. Recognising the context here where the given integral when the order is $dydx$ is the sum of two integrals is applicable in the given problem situation calls for decapsulating the object from the process it came from. However here the student has given the inner function of the second integral as a function of y whereas it should be given as a function of x.

One student responded with: $\int_0^1 \int_0^2 \sigma dy\, dx + \int_1^{\sqrt{3}} \int_{3-x^2}^0 \sigma dy\, dx$

This student is in the action stage as shows an understanding of the limits of boundary curves however there is a swapping around of upper and lower limits.

One student responded with: $\int_0^2 \int_0^3 \sigma dy\, dx$

As with the similar $dxdy$ construction this represents a failure of prerequisite knowledge.

One student responded with: $\int_0^{\sqrt{3}} \int_{3-x^2}^2 \sigma dy\, dx$

This student has a vague grasp of how to set up integrals but seems to lack geometric understanding of what the limits represent. This represents a failure of prerequisite knowledge.

One student responded with: $\int_0^{\sqrt{3-y}} \int_0^2 \sigma dy\, dx$

Here there is merely a swapping of the limits from the $dxdy$ form. Fundamental knowledge when setting up double integrals requires firstly to focus on the inner integral and to consider the limits of that integral that are boundary curves defined as functions of x. It is worrisome that the limits on the integral on the outer integral are functions of y and therefore not constant making the integral meaningless.

One student responded with: $\int_{-\sqrt{3}}^{\sqrt{3}} \int_0^2 \sigma dy\, dx$

This is a reflection of student thinking that intersections and roots of functions are often limits of integration. Here student has solved for roots of $y = 3 - x^2$ and used as limits. There is a failure to relate these roots to the diagram and hence to the limits of integration.

4. SUMMARY AND FUTURE RESEARCH

Although this is a pilot study and the findings cannot be generalised the APOS theory provided a valuable exploration of the learning of the limits of integration of double integrals in a vector calculus class. We note that the part of the question that required the action level of understanding, setting up a double integral with limits of integration over a type 1 region or a type 2 region, was well within the capabilities of the majority of the students. However, the responses to the part of the question requiring an object level of understanding of limits of a double integral were problematic for a number of students. Although a graphical representation was given students found difficulty in identifying the region of integration. The majority of those students who had difficulty merely followed steps without acknowledging visually the shape of the region which warranted that it be represented as a sum of two double integrals. This suggests that the students' engagement of the concept of a double integral and how it refers to the region is not well grounded.

In partially answering our research question at this stage of analysis in the research project, we observe that some students find difficulty with recognising the region of integration if it is other than rectangular, some find difficulty when dealing with integration first with respect to y and there is no understanding that the limits of integration of the inner integral are functions of x and similarly for the integration with respect to x first, and others lack a geometric understanding of what the limits of integration represent.

Important insights have been gained from students' mental constructions of limits of integration for double integrals which the next cycle of teaching will focus on. Reflecting on teaching this concept, more consideration will be given to graphical representation of regions and how the choice of integration in one direction first and then the other depends on the region of integration and hence implies the choice of limits of integration.

This pilot study has not only provided valuable insights on students' mental constructions of double integrals but has also illustrated the potential of the APOS framework to be used in future research and to influence teaching and learning of vector calculus concepts. This aligns with our intention to present implications for the teaching and learning of Vector Calculus concepts that promote deeper conceptual understanding.

The next stage of this research would involve exploring student understanding of the limits of integration of double integrals with a larger population and, as initially intended, the comparison with the second research cohort including probing of this understanding using interviews. We suggest that future research could study the impact of such teaching of double integrals on students' learning.

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A STYDY OF SOME FACTORS INFLUENCING PROGRESSIOM AND PERFORMANCE OUTCOMES OF OVERSEAS STUDENTS AT A UK UNIVERSITY

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ABSTRACT

The ever increasing diversity of the student population within the higher education sector presents challenges for educators. Universities need to adapt in order to provide inclusive learning environments that meet these students' varying educational needs, as well as to develop appropriate support mechanisms. In particular, a fundamental requirement is the development of a better understanding of the needs of international students, who are often learning in a second language, in addition to experiencing unique cultural, social, and financial challenges. An improved understanding can potentially assist in developing guidelines and best practice for supporting these groups of students.

This study looks at whether perceptions of lower progress and outcomes for international students progressing into year 2 of Mechanical and Aerospace Engineering undergraduate degrees at Queen's University Belfast, from a diploma programme, are valid. Their performance is tracked from their diploma year, through to graduation. In order to isolate areas of concern particular to the international student group, results are compared with a control group of UK students also progressing into year 2 from a Foundation Degree programme. We also report on qualitative surveys carried out to identify areas that the students perceive to be problematic. It was found that while the international students experienced minor practical difficulties, they actually perfomed better than the comparison group. It appeared that difficulties were more related to joining the programme at year 2 rather than year 1, and the expected transition issues unique to international students may have already been addressed during their diploma year.

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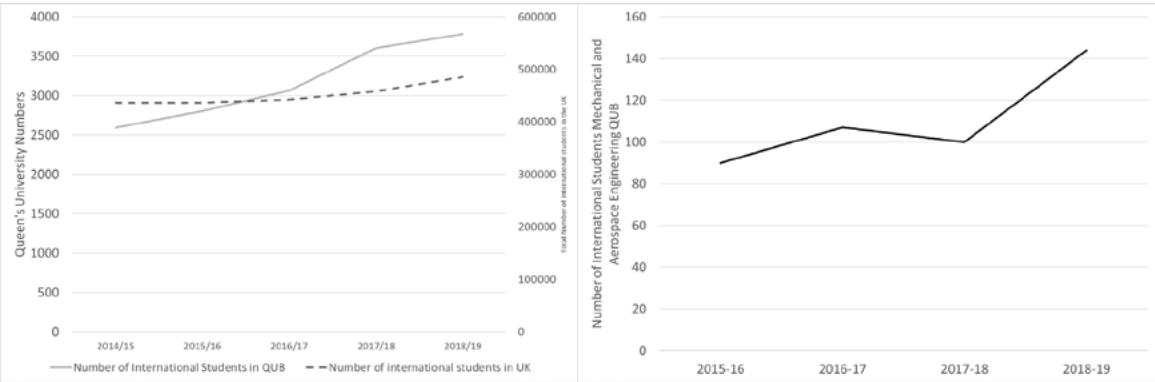
1 INTRODUCTION

1.1 Increasing Internationalisation in Higher Education

The past decade has shown a steady increase in the number of international students choosing to study in the UK. Data from the Higher Education Statistics Agency (HESA) shows that overall numbers of international students increased by 11% in the five year period from 2014 to 2018. A particularly significant increase has been seen in the Northern Ireland region, which would have traditionally had low numbers of international students. In the same 5-year period Queen's University Belfast (QUB) saw a 46% increase in the number of international students. Within the School of Mechanical and Aerospace Engineering (SMAE) at QUB, this trend was also seen with a 59% increase in international student numbers between 2015 and 2018. These trends are illustrated in Figure 1.



(a) *(b)*

Figure 1: Trends in international student numbers from 2014 to 2018 (a) QUB and UK Totals (data source: HESA) and (b) School of Mechanical and Aerospace Engineering at QUB (UG and PG)

1.2 Challenges of Internationalisation

The performance of international students, in particular those who are studying in a second language, can fall below expectations for certain groups. Varying factors, including different countries of origin (and thus previous educational background), differing cultural norms, and English language proficiency, can result in poorer outcomes. For example a study by Li et al [1] showed a correlation between poorer performance of Chinese students compared to other international students due to English language ability and more difficulties with social integration in UK universities, while Rienties et al [2] found good social and academic integration of international students from Western countries, but lower academic and social integration from non-Western students.

In terms of the relative effect of these factors, English language proficiency is an obvious challenge, particularly for Engineering students who are faced with the additional challenges of technical English [3–5]. A study by Mulligan et al showed numerous difficulties faced by students from non-English speaking backgrounds, with a majority reporting significant difficulty understanding lecture, taking notes, and gaining deeper understanding [6].

1.3 Rationale for the Study

The School of Mechanical and Aerospace Engineering at Queen's University Belfast has a current undergraduate enrolment of 730 students, 110 of whom are international students. Within the school, there has been a general perception that international students have poorer outcomes than local students in undergraduate degree programmes. In order to assess the validity of this perception and address any potential underlying issues, initial steps were taken to better analyse the data that is available for these students and determine if there are any trends that can be identified. This paper presents the initial work that was carried out, with the three aims as follows:

- To track the performance of a group of international students from entry to an undergraduate degree in the School of Mechanical and Aerospace Engineering through to completion;
- To track a comparable control group of local students;
- To aim to identify any unique areas of difficulty for the groups.

2 METHODOLOGY

2.1 Selected Groups

Entry into undergraduate programmes in the United Kingdom generally occurs after the completion of the equivalent of A level study, and students progress into year 1 of their degree programme. As there are limited numbers of international students entering the SMAE programmes via this "standard" route, two other groups of students were selected for comparison, both of whom join the programme at year 2, after a period of study elsewhere.

(a) INTO students (International Students)

Queen's University partners with a pathway provider, INTO University Partnerships, and the largest number of international undergraduate students in SMAE come via this route. The vast majority of these students are from Asian and Middle Eastern countries, and most students progressing into engineering degrees come from a one year diploma programme. This programme offers the students the opportunity to study at the equivalent of year one, but in much smaller classes. Students also attend English language classes in addition to their subject modules. On successful completion of the programme, students may progress directly into year 2 of the university undergraduate programme. Progression requirements are that the students obtain a minimum of a 60% module average, with passes in all 10 engineering modules, in addition to achieving the required English Language standard (equivalent to IELTS 6.0).

(b) Foundation degree students (UK nationals)

It was felt that comparing the INTO students directly to UK national students entering by a conventional route into year 1 was problematic, for two reasons:

1. The minimum required academic qualifications for entry to the INTO Year 1 Diploma programme is lower than for students directly entering Year 1 of their undergraduate degree through the conventional route.
2. The effect of joining a degree programme at year 1 vs year 2 may be significant.

It was therefore decided to select a group of UK students who progressed to the University via a Foundation Degree (FD) at Belfast Metropolitan College (BMC), a local further education college. These students are more comparable as the minimum entry requirements are similar to the INTO programme, and the students also join the main degree programme at year 2. Requirements for progression are a 55% module average, with passes in all elements of all modules.

2.2 Analysis of Perfomance

An analysis of the data available for both sets of students was carried out. The numbers of students commencing on the Foundation Degree or INTO Diploma programme were tracked through to the numbers progressing into SMAE. The performance of both sets of students admitted between 2010 and 2018 across the stages was analysed, and the final degree classifications compared.

2.3 Student survey

Students from the two groups were surveyed in order to assess their perceptions and views in a number of areas including practical and social issues, transition issues moving from foundation study to the main university, and academic issues. Surveys were sent to all relevant students active in SMAE degree programmes in June 2019 from the two entry routes. For comparison purposes, a group of INTO students who were at the end of their year at INTO were asked the same questions about their experience at INTO, in order to assess any bias in perceptions due to the passage of time.A 5 point likert scale was used, and responses were collated and weighted to give an average score out of 10 for each question. For some issues, such as those relating to language, questions were omitted from the FD student survey.

3 RESULTS

3.1 Performance and Outcomes

Table 1 shows the completion data from students who first joined the FD programme, or the INTO Diploma programme between the years 2010-2015. It can be seen that the percentage of INTO students who were eligible to progress into SMAE from the programme was higher, at 80%, than the eligible percentage from the foundation degree 72%, and the actual percentage who chose to continue into year 2 was 75% compared with 61% respectively . In addition to this, the percentage graduating, and graduating with either a 1st class or 2:1 degree classification is also notably higher for the INTO cohorts.

Table 1. Performance of UK Foundation Degree Students and the INTO International students

	Foundation Degree		INTO Diploma	
	Number	**% of enrolled students**	**Number**	**% of enrolled students**
Students enrolled on initial programme	140		99	
Students eligible to progress into year 2 SMAE	101	72%	79	80%
Students actually progressing into year 2 SMAE	85	61%	74	75%
	Number	**% of stage 2 entrants**	**Number**	**% of stage 2 entrants**
Graduated students	67	79%	60	81%
Students obtaining 1st class degree	4	5%	7	9%
Students obtaining 2:1 degree	16	19%	17	23%
Students obtaining 2:2 degree	35	41%	23	31%
Students obtaining 3rd class degree	10	12%	10	14%
Students obtaining BSc ordinary degree	2	2%	3	4%
Students withdrawn/Failed/Not completed	18	21%	14	19%

3.2 Survey Results

Results were collated from the surveys. Responses were obtained from 12 students who were just finishing their year at INTO (35% response rate), and 19 ex-INTO students who had subsequently transitioned into QUB (28% response rate). There was a more limited response was obtained to the foundation degree student survey, with only 7 responses (20% response rate).

3.2.1 Practical Issues

The results from questions around practical issues such as orientation, registration, and accommodation issues are presented in Table 2. Among INTO students and FD students, satisfaction levels with practical issues were generally high at both stages. Ex-INTO students looking back on their time at INTO had slightly higher perceptions of the ease of issues compared with current INTO students, but the differences were not very significant. For FD students financial issues were the most difficult, and this continued at both stages.

Table 2. Ratings for question "How easy were the following practical issues"

	INTO Students surveyed at end of INTO year	INTO students surveyed during time at QUB **about their time at INTO**	INTO students surveyed during time at QUB **about their time at QUB**	Foundation degree students surveyed during time at QUB **about their time in foundation degree**	Foundation degree students surveyed during time at QUB **about their time in QUB**
Organising transport, visas, travel documents	7.5	7.50	7.37		
Completing registration forms	7.17	8.24	7.5	8.57	8.57
Organising accommodation	7.5	7.79	7.19	6.88	8.33
Orientation (finding your way around, knowing where things are)	7.69	7.94	8	7.86	8.21
Adjusting to the climate	6.43	7.34	8		
Managing finances	7.32	8.13	8.03	6.07	6.07
Making friends	7.68	7.79	7.03	8.57	6.43
Coping with the language	7.88	8.01	7.5		
Homesickness, missing family and friends	7.12	7.33	7.66	8.33	8.33
Cooking, cleaning, shopping	8.33	7.94	8.09	8.5	9.28
Average	**7.46**	**7.80**	**7.64**	**7.83**	**7.98**

The INTO students initially found the most difficult issue "adjusting to the climate", with many originating from countries with much warmer and drier weather than Northern Ireland, although this improved significantly by the time the students transitioned into year 2 at university. Issues with homesickness, finances and orientation showed modest improvements between the INTO year and year 2, in line with reasonable expectations as the students become more accustomed to living abroad. At odds with this however, is the small decrease in how the INTO students coped with the language, as this would also be expected to increase after a year spent in an English speaking environment.

The largest decrease for the INTO students was in the ease with which they felt they could make friends, again this is not unexpected due to transitioning to a much bigger class size, integrating culturally with local students, and also perhaps due to entering the programme at year 2, when social groups would already have been established among students who entered the university at year 1. What is particularly striking, and more unexpected, is that this difficulty in establishing friend groups is even more pronounced among the local students transitioning into stage 2, which would seem to indicate that the transition at year 2 itself is more problematic than language or cultural issues from a social perspective. Comments from both the INTO students and the local students on this issue were very similar when asked what was difficult about the learning environment, and what advice they would give to others, as shown in Table 3.

Table 3. Selection of comments illustrating difficulties in social integration

INTO Student Comments	*"Having no friends in class just those who came from INTO"* *"A lot of the students already have formed their own friend group when you enter during stage 2, so it's a bit difficult to make friends with existing students. I found myself making friends with new entry students like myself."*
Foundation Student Comments	*"Students joining QUB from BMC may find it harder to make friends with students who started QUB at stage 1, however interact with them and try talk to other students - having friends who are doing the same course is really useful for help with exams and assignments etc."* *"The academic transition is fine. It's the social element that can be hard but if you have made friends [during Foundation Degree] and they're in your position you can stick together. Eventually you make friends from the QUB class but takes time"*

3.2.2 Course Content

The results relating to the students' experiences of the course content, and their preparedness for study at each level are presented in Table 4. In all areas, other than the expectations of course content and difficulty levels, the INTO students were less confident with their ability to cope with the course content at university compared to their INTO year.

Both INTO students and local students felt less confident with their Mathematical knowledge when transitioning to university than they had done previously. They also both showed a drop in their interest levels on transitioning to year 2. On the first point this may just be attributable to a natural increase in the level of difficulty, or may be due to the fact that students entering directly to year 1 of the degree programme are required to have at least a B grade in A level Mathematics. The second point may be due to normal academic fatigue, or recognised problems around motivation on transition to university [7,8]. It would be interesting to compare both areas in direct entry students transitioning from year 1 to year 2.

Table 4. Ratings for question "What was your experience of the course and module content?"

	INTO Students surveyed at end of INTO year about INTO	INTO students surveyed during time at QUB **about their time at INTO**	INTO students surveyed during time at QUB **about their time at QUB**	Foundation degree students surveyed during time at QUB **about their time in foundation degree**	Foundation degree students surveyed during time at QUB **about their time in QUB**
The classes were at the right level of difficulty	6	5.94	6.05		
You were prepared for the level of study	7.5	7.34	6.45	7.14	7.5
You were interested in the subjects	8.04	7.50	7.11	8.21	7.5
Your existing knowledge of Mathematics was sufficient to allow you to understand	7.83	8.28	6.84	8.93	7.86
Your existing level of English was sufficient to allow you to understand	8.17	7.97	7.24		
The course content was as you expected	7	7.34	6.58	7.86	8.21
Average	7.51	7.41	6.74	7.68	7.68

3.2.3 Teaching

Table 5 shows the satisfaction levels of the students relating to teaching at both their pre-university year and at university. The results for both INTO students and the FD students were remarkably similar, with INTO students showing an average satisfaction in this area of 7.65 while at INTO, 8.42 for those looking back at their INTO experience, and 6.77 while at QUB, and FD showing satisfaction of 7.85 looking back at their foundation degree, dropping to 6.19 at QUB.

Table 5. Ratings for question "What was your experience of teaching?"

	INTO Students surveyed at end of INTO year about INTO	INTO students surveyed during time at QUB **about their time at INTO**	INTO students surveyed during time at QUB **about their time at QUB**	Foundation degree students surveyed during time at QUB **about their time in foundation degree**	Foundation degree students surveyed during time at QUB **about their time in QUB**
Spoke at the correct pace	7.86	7.81	6.97		
Used language that you could understand	8	8.13	6.97	8.21	7.5
Were prepared to help you individually	7.33	8.28	6.45	8.14	5.71
Made the content clear and easy to understand	7.5	8.44	6.71	7.5	6.07
Responded to feedback from the class	7	8.91	6.71		
Gave you appropriate feedback	7.5	8.91	6.84	7.86	6.07
Provided you with the information you needed	7.83	8.75	6.71	8.21	7.14
Used helpful resources	8	8.44	7.11		
Encouraged you to participate	7.83	8.13	6.45	7.14	5.71
Average	**7.65**	**8.42**	**6.77**	**7.85**	**6.19**

It would appear that these differences in experience are mainly due to the transition from small group teaching to very large class sizes, and the more anonymous environment of the university, as illustrated by comments in Table 6.

Table 6. Selection of comments illustrating difficulties in transition to large lecture teaching

INTO Student Comments	*"Very big lecture theatre. No individual attention. Difficult to ask questions"* *"could easily approach professors in INTO for help but wasn't that easy to approach the professors at University that easily"*
Foundation Student Comments	*"Because of the lack of contact and communication between students and lecturers, the learning* *"Less caring than the [Foundation degree] lecturers"*

4 SUMMARY

Tracking the performance of two specific populations of international students and UK students, both entering undergraduate degrees in Mechanical and Aerospace Engineering at year 2, shows that a higher percentage of the international students successfully complete their initial period of study and achieve their progression requirements than the UK students.

Both UK and international students struggled socially when they moved into year 2 in the university, and showed significant drops in the ease of forming friendship groups. On other practical issues, the international students coped well overall, finding the greatest difficulty in adjusting to the colder climate initially. Most practical issues became easier over time, with the exception of a small increase in difficulty coping with the language, presumably due to moving to a large lecture based programme. UK students on the other hand found most difficulty in managing their finances, and this persisted as an issue before and after their transition.

In terms of academic content, the international students experienced a drop in confidence levels and in feelings of preparedness in most areas when transitioning into university. The local students displayed only a drop in their

confidence with mathematics. Both groups showed lower interest levels after transitioning to stage 2. Both groups of students showed clear preference for the small group teaching that they had experienced in their foundation programmes, and drops in satisfaction levels were found across all areas for both groups on transitioning to university.

Final outcomes for the students showed a slightly higher percentage of international students completing the degree, compared to the UK students, and a notably higher percentage of international students achieving first class or 2:1 degree classifications. This suggests potentially higher levels of motivation or resilience in the international cohort.

The practical implications of this study suggest that more work needs to be done to assist the transition of students who are entering degree programmes at a different stage to the main student body, regardless of the origin of the students.

Further work will be carried out to assess the performance of international students entering at year 1 compared to UK students entering at year 1 once the population size is sufficient. The effect of having a transition year in small classes in assisting international students to settle into a new country should be assessed, as many of the expected difficulties for international students seem to already have been resolved during the diploma year for this cohort. A study of the effect of different nationalities and native languages will also be considered.

5 ACKNOWLEDGMENTS

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TEACHING PROBLEM SOLVING SKILLS BY STRATEGY TRAININGS IN PHYSICS

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Conference Key Areas: *physics in the engineering curriculum, linking different disciplines both inside and outside engineering*
Keywords: *problem solving, worked-examples, strategy training, physics*

ABSTRACT

Nowadays the expectations and requirements for engineers keep changing and involve besides technical, interdisciplinary and project management competencies, in particular problem solving skills [1].
It has been shown that implicit teaching of problem solving strategies fails. The results are missing approaches, no linkage to the existing knowledge and the failure of a solution. [2]
However, there is a very well evaluated state of research how novices and experts solve physics problems. Experts use problem schemes, which include heuristics and exemplary problems that ease the process of generating proper solutions and make the process much less error-prone. [3]
Therefore, the aim of this study is to develop a strategy training, which contains a strategy exercise and adjusted learning material to promote the problem solving competence of first year engineering students.
To implement such a strategy training in the regular physics exercise, a manual concerning different task characteristics has been developed. The resulting categories have been used to create a compilation of tasks, which are suitable for analysing the fitting heuristics. To measure the effect of the new learning material and the strategy training a 2x2-design was chosen to examine the influence of either one of those variables. The pre-post-evaluation will focus on questionnaires considering the stages of the problem solving process.

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1. INTRODUCTION

Since problem solving competence in general is one of the most central requirements for engineers [1], it is reasonable to promote this skill as early as possible. At the beginning of various engineering study programs students attend physics courses, which often include weekly exercise assignments. These physics exercises represent knowledge-based problems, which are intended to train the problem solving competence.

Novices in physics thereby use an inefficient plug-and-chuck-procedure by searching for a suitable formula for the wanted variable [4]. This approach prevents a focused strategy that is a condition for a more efficient and understanding way of working [4]. For this reason it is necessary to teach problem solving strategies in an explicit way [2].

1.1 Knowledge-based problem solving

Typical physics tasks can be described by Friege's model of knowledge-based problem solving. The model considers in particular the difference between the solution process of experts and novices. Therefore experts are able to use problem schemes, which contain different solution approaches and heuristics of the corresponding physics concept. That's why they are able to use structural knowledge for the elaboration of a task. In contrast novices don't have those problem schemes yet, so that they have to solve a great number of exemplary problems to develop them. The elaboration of a solution without problem schemes is also very error-prone. [3]

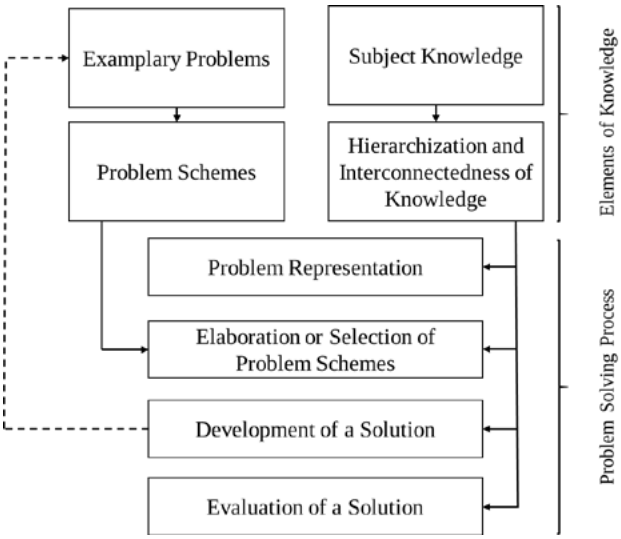

Fig. 1 Model of knowledge-based problem solving by Friege [3]*, translated*

Since weak problem solvers fail more often because of the planning phase and strong problem solvers fail in particular because of careless mistakes, it is questionable, if their ability to consider the deep structure of a task influences the problem solving strategy in general [5].

In addition, first year students start with very heterogeneous backgrounds of subject knowledge and problem solving skills, so that they don't achieve satisfactory problem solving strategies at the end of the semester [6]. It has to be evaluated whether the guidance of a reflection process will be able to establish the needed problem schemes.

1.2 Worked-Examples

A well established way of focusing on the principles behind a given problem, is to use worked-examples [7]. This enables a learning process which starts with learning aids that can be removed over time in the sense of a scaffolding approach. Whereas learning from worked-examples is very effective for the initial acquisition of cognitive skills in well structured-domains like physics [7], the purpose is to achieve an independent approach of problem solving in the end. Since the effectiveness of this method depends mainly on the self-explanation of the learners [8], it is important to initiate this aspect by using additional prompts. Consequently the use of worked-examples with well adjusted prompts in the beginning and fading learning aids during the semester allow a guided structure that leads to independent problem solving of the students and reduces unnecessary cognitive load.

2. STUDY APPROACH

Because of the students' lacking strategical methods to solve physics tasks, these will be developed through an exercise concept, which focuses on generating problem schemes. This exercise consists of two complementary interventions. On one hand a strategy exercise will be implemented, which instructs a reflection process on the students' methodological approach, on the other hand learning material will be designed, which uses worked examples and allows a reasonable handling of surface and deep structure characteristics.

The main approach of this study is to examine the influence of both strategy exercise and prestructured learning material on the problem solving competence of first year engineer students.

3. METHOD AND DESIGN

Since there are two different independent variables in this study, it is necessary to evaluate the influence of each aspect individually. Therefore a 2x2-design has been chosen. This means that there are four different exercise groups in which all combinations of the intervention are realised (Fig. 2). The intervention is implemented in the regular physics exercise related to the given lecture. Additionally a new compulsory exercise is established to ensure that all groups deal with the corresponding material to the same extent. During the exercise the students work on their learning material and

		Desgined Learning Material	
		No	Yes
Strategy Exercise	No	Group I	Group II
	Yes	Group III	Group IV

Fig. 2. 2x2-Design of the intervention

have the option to ask subject related questions. Nevertheless there is no instructional aspect that influences the process. At the end of each exercise the students submit their work to receive individual feedback and achieve the qualification for the final exam. This framework ensures the necessary commitment of the students.

4. LEARNING MATERIAL

4.1 Task characteristics

In order to create a functioning strategy training, suitable tasks must be generated first. Since the specific problem schemes include corresponding problem types, solution approaches and heuristics, the tasks need to be organized according to the referring deep structure. Therefore it's necessary to develop a system that measures these task features. For this reason all complexity producing characteristics were summarized in a manual for the construction of the new tasks. Those characteristics relate to both surface and deep structure.

Table 1. Varied Task Characteristics

Task Characteristic	Function	Categories
Subject Content	Identifying tasks with mixed contents or multiple solutions	kinematics, forces, energy, momentum
Solution Approach	Generating similar deep structures	Top categories (with 66 subcategories): mathematical supplement, uniform motion, motion with constant acceleration, multidimensional motion, circular motion, forces, energy, momentum, rotation
Hierarchical Complexity	Increase during the semester and each content area	basic process description, basic linear causality, adapted process description, adapted linear causality, composed multivariate interdependence, multivariate interdependence
Scaffolding	Scaffolding during the semester	Subcategories: Number of intermediate tasks, standardised complexity, Scaffolding-Index
Mathematization	Increase of mathematization	no mathematization, calculation, converting, handling functional relations, modelling
Possible Solutions	Identifying tasks to illustrate advantages and disadvantages of different possible solution approaches	One solution, multiple solutions, one preferred solution

The dimension 'subject content' includes the three areas of the lecture: kinematics, forces and the conservation of energy and momentum.

The 'hierarchical complexity' leaned on the model of Bernholt [9] was adapted in order to consider the used learning tasks. The complexity increases gradually during the semester.

The category 'Scaffolding' measures the number of learning aids in relation to the corresponding complexity of every task. The final Scaffolding-Index determines the average standardised complexity per exercise sheet and increases during the semester.

The dimension 'possible solutions' indicates, if there are multiple ways to solve the given problem and if one of those possibilities should be preferred. This dimension is relevant to identify tasks, which can be used to reflect upon the advantages of different approaches to the same problem. This aspect will be considered in the continuing strategy exercise (s. Chapter 5).

The characteristics that function as control variables and are kept constant on one level are described in Table 2.

Table 2. Controlled Task Characteristics

Task Characteristic	Categories
Subject Level	school knowledge, deepened knowledge, university knowledge
Subtasks	No subtasks, interdependent subtasks, independent subtasks
Type of Task Information	Text, picture, graphic, table, diagram, numbers, others
Relevance of Task Information	only solution relevant, additional text information, additional other information
Readability (LIX) [10]	Values between 0 and 100

The current state of research has shown that the contextualization can hardly be determined by the present models. According to this, a prior investigation on this topic is considered for the pilot testing.

4.2 Developing new tasks

Since most of the described characteristics are control variables, because they would be complexity producing, the corresponding levels are kept constant. The features that are varied in this research are subject content, hierarchical complexity, scaffolding and solution approach. The subject content differs by the three main topics and the hierarchical complexity increases during each topic and the whole semester.

The main part of the construction was to build tasks with the same deep structure. To be able to teach the heuristics to the essential physics problems, it is necessary that the similarity of the deep structure is as high as possible. Since the novices have less experience with physics problems, the classification of problems and solution approaches was chosen as specific as possible. In order to compare the deep structure of the tasks, every solution was rated as a combination of solution approaches. Because of their specifity they only represent a part of the solution or the superior problem type, so that the complete problem can be represented as a sum of the corresponding solution approaches. Therefore the dimension 'solution approach' was developed.
To illustrate the described procedure an example is presented below.

Ball throw
A ball is thrown vertically. The discharge altitude is $y_0 = 1{,}5\mathrm{m}$ and the initial velocity $v_0 = 15\frac{\mathrm{m}}{\mathrm{s}}$.

a) Calculate when the ball will reach the highest point
b) Calculate the maximum altitude y_s it will reach.
c) Calculate when the ball hits the ground.
d) Calculate when it is $6\mathrm{m}$ above the ground.
e) Calculate when the ball will return to its initial height on the way down.
f) Plot the velocity v and the current altitude y as a function of t.

The example contains the following solution approaches:
Vertical throw, Calculation of a specific time (e.g. fall time), graphical illustration of the location of a motion with constant acceleration, graphical illustration of the velocity of a motion with constant acceleration
Note: The specific solution approach *vertical throw* contains another solution approach *using the equation of a motion with constant acceleration* $s(t)$, which is otherwise recorded separately.

By using this classification, it is possible to represent the deep structure of each task and to compare the necessary solution steps. Consequently, the different problems can be easily adjusted to be more or less alike, depending on the respective phase of the semester. Therefore the tasks in the beginning have the purpose to understand the underlying problem type, whereas the later ones enable the ability to identify and transfer a suitable solution approach to a modified problem.

4.3 Worked examples

Besides the main structure of each used task, there is also a worked example at the beginning of every exercise sheet. The worked example consists of a problem, its explained solution and a compilation of prompts. The prompts' function is to outline

the important explanation steps of each problem type to ease the following solution of the regular tasks with the same deep structure. The combination of self-explaining and explicit strategy exercise aims for synergetic effects.

5. STRATEGY EXERCISE

The strategy exercise represents the second part of this studys' intervention. Because of the 2x2-design, there are two groups that participate in the strategy training. One of them works with the developed learning material the other one doesn't.

5.1 Learning Outcomes

To illustrate the specific design of the strategy exercise, the related learning outcomes are listed below (Table 3).

Table 3. Learning outcomes

The students are able to…
…reflect on their methodological proceeding of solving physics tasks and name the strengths and weaknesses of their actions.
…name the additional value of a strategical procedure compared with the plug-and-chuck-procedure.
…name and use the relevant problem schemes consisting of problem type and heuristic.
…name the typical task characteristics of the relevant problem types and identify them in corresponding tasks.
…name and use the solution approaches of the relevant problem types.
…match tasks by their knowledge about problem schemes to a corresponding solution approach.
…decide by their knowledge about problem schemes, if a heuristic of a certain content area is suitable for a solution.

The subject related learning outcomes apply to each of the different content areas.

5.2 Teaching Method

In order to achieve these aims the teaching of problem solving strategies is realized in an explicit way.
At the beginning the students have to solve different problems with similar surface characteristics and a different deep structure. To illustrate the limits of the familiar formulas and strategies, only one of the problems can be solved by the current knowledge. This demonstrates the necessity of a more reliable procedure.
Subsequently one task will be used to abstract the referring solution approaches, problem type and typical task characteristics. In the following step the students will perform

this procedure on their own. The result will be an overview of the relevant aspects for each topic. To ensure the active use of the generated meta structures, the students match the prepared tasks to the related features. That way they train the identification of the established schemes in the actual realization.
To strengthen a systematic approach the students participate in little quizzes on deciding if a certain heuristic fits the given task and to specify the corresponding problem type and solution approach.
Therefore the strategy exercise consists of the following elements:

Table 4. Overview of the strategy training

Teaching Subject	Teaching method	Example
Awareness of the necessity of a reliable strategy	Produce a cognitive conflict by using various problem types which don't fit the current state of knowledge	Problems that describe different motion types, including some that are not known yet
Knowledge about different solution approaches	Abstracting the solution approaches of one task as a prototype to enable the transfer to further examples	A problem type in kinematics: e.g. horizontal throw
Knowledge about different problem types	Abstracting the problem type of one task as a prototype to enable the transfer to further examples	A solution approach in kinematics: e.g. $y(t) = 0$ to calculate a fall time
Knowledge about typical task characteristics	Abstracting the typical characteristics of one task as a prototype to enable the transfer to further examples	a task characteristic of a horizontal throw is a horizontal initial velocity
Knowledge about different heuristics	Generating the heuristic of one concept by abstracting the parallels of the procedures for the different problem types	The heuristic for kinematics starts with the identification of the given type of motion.

6. PRELIMINARY RESULTS

Since the implementation of the described intervention won't be piloted until the next semester, there are only results concerning the theoretical analysis that has been made. For now the objectivity of the underlying rating manual was evaluated by the rating of the current task collection of the institute (91 tasks). The dimension 'Scaffolding' could not be examined yet, since it only relates to the new tasks. The interrater reliabilities of the three raters are given in Table 5.

Table 5. Interrater reliability of the examined task characteristics

Task Characteristic	***Interrater Reliability*** κ	***Significance*** p
Subject Content	.61 - .86	.000
Solution Approach	.76 - .95	.000
Subject Level	.89	.000
Hierarchical Complexity	.88 - .91	.000
Possible Solutions	.94	.000
Mathematization	.96	.000
Subtasks	.95	.000
Type of Task Information	.73 - 1.0	.000
Relevance of Task Information	.80	.000
Readability (LIX) [10]	1.0	.000

Since the interrater reliability is between $\kappa = .61$ and $\kappa = 1.00$ the objectivity of the manual can be accepted.

7. SUMMARY AND PERSPECTIVE

The problem solving skill is one of the essential requirements for a modern engineer. Most engineering programs start with a physics course at the very beginning, where currently the use of fitting strategies are missing. Therefore the knowledge about problem schemes of experts in knowledge-based problem solving is used to design an intervention that teaches content related approaches as well as general heuristics to improve the students' problem solving competence.

The designed learning material combines worked-examples and a task compilation, which considers the referring deep structure. The strategy exercise teaches knowledge about certain problem types and their solution approaches to focus on a more general heuristics, which allows an independent problem solving process.

The analysis of relevant task characteristics was operationalized as a rating manual. Its objectivity could be verified by a sufficient interrater reliability. The deep structure of the new tasks was aligned with these aspects.

The next step will be a pilot phase, which includes the implementation of both interventions. Additionally the necessary testing instruments will be examined. This includes prior knowledge in physics and mathematics, linguistic competence and problem solving performance. For a differentiated analysis a test concerning the declarative knowledge of problem schemes will be developed.

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THE SENIOR UNIVERSITY TEACHING QUALIFICATION: ENGAGING IN RESEARCH, DESIGN AND BUILDING COMMUNITY IN ENGINEERING EDUCATION

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Abstract

For a high standard of educational quality and success rates, teaching quality is key. Teachers need to be supported in their professional development aimed at achieving the ambitious goals of student-driven engineering education. Moreover, educational excellence is often confined to 'pockets': good practices are confined to one program or department and not shared beyond. Creating opportunities for teachers to collaboratively reflect on, further develop and share knowledge and practice-based research to promote educational innovation is very important. The Senior University Teaching Qualification (SUTQ) is focused on a scholarly approach of teaching and learning (SoTL; Graham, 2018), in which teachers are regarded as researcher and designer of their own educational practice, to collaboratively innovate and improve teaching.

SUTQ participants determine their personal learning path and execute their own sub-project (160 hours) to innovate and improve their practice. They are supported by a coach, educational research and design seminars, and peer-feedback from colleagues. After three years of running and adjusting this approach based on the literature, evaluations, experiences and outcomes, this paper shows both the

benefits and the challenges of organizing this type of professional development. Although participants feel inspired, appreciate the clarity, usefulness and feedback during SUTQ sessions, some challenges remain both in terms of facilitation (e.g., time) and the approach (e.g., the steps from clear problem statement to innovation design). Additionally, community-building needs more attention, to promote further continuous development in the university as a whole. In this concept paper we set out an agenda for doing so.

1 INTRODUCTION

1.1 The senior university teaching qualification

Teaching quality is key for a high standard of educational quality and success rates. To achieve the ambitious goals of student-driven engineering education, teachers need to be supported in their professional development. Moreover, educational excellence is often confined to 'pockets': good practices are confined to one program or department and not shared beyond. Creating opportunities for teachers to collaboratively reflect on, further develop and share knowledge and practice-based research to promote educational innovation is important. The Senior University Teaching Qualification (SUTQ) is focused on a scholarly approach of teaching and learning (SoTL) [1], in which teachers are regarded as researcher and designer of their own educational practice, to collaboratively innovate and improve teaching.

SUTQ participants determine their personal learning path and execute their own sub-project (160 hours) to innovate and improve their practice. They are supported by a coach, educational research and design seminars, and peer-feedback from colleagues. After running this program twice and adjustments based on the literature, evaluations, experiences and outcomes, this paper shows both the benefits and the challenges of organizing this type of professional development, and what needs further attention to make it even more succesful both for individual teachers and the university as a whole.

1.2 Framework and design

1.2.1 SUTQ vision and goals

At this University the career framework for university teaching [1] is used, referring to four levels (see Figure 1). Based on this career framework for teaching, teachers develop their competencies via SUTQ at the level of the 'skilled and collegial teacher' (2nd level), ready to contribute to the pedagogical knowledge in their own field of teaching (3rd level, of the 'scholarly teacher'). The target group for participation in SUTQ are (experienced) teachers that have both obtained their basic University Teaching Qualification (UTQ), and are considered forerunners in their department in terms of teaching.

Participants are expected to

- be committed to and focused on improving education focused on student learning
- be critical and proactive concerning education and their own role
- be informed of and have an open mind for state of the art developments in the field of education
- give direction to and are in control of their professionalization
- be committed to the activities and collaborate with fellow participants during the SUTQ trajectory

1.2.2 Approach

The SUTQ trajectory consists of an intake, a two-hour kick-off meeting to explain the program and to get to know all participants, and several 'research and development' seminars about educational (design) research over a period of a year (may-april). Support is available in the form of (group) coaches intervision sessions, group (lunch and/or writing) meetings and individual feedback from the coaches. The seminars are scheduled from late afternoon, to and including the evening (around 8 pm, including dinner). For each participant resources for work visits, participation in (international) workshops or conferences are also available. A digital learning environment was set up to inform participants and coordinate the program. Characteristics such as a longer-term program (a trajectory of activities rather than one-shot workshops), structured and guided activities related to practice and a (collective) focus on student learning, as applied in this program, are important conditions for effective professional development [2].

In the first pilot program, 17 teachers participated, ranging from teachers/researchers to professors from a variety of faculties and educational programmes. The intake consisted of a meeting between the SUTQ coordinators, the participant and their director of education. Directors of education were involved to explain SUTQ to them – given that this was new at the University. Because of their role of final assessor (one of the assessors), it was important to clarify this role and responsibility. Additionally, we aimed for directors' support of the teachers' participation in SUTQ. Participants are doing research in their practice that is usually also relevant for colleague teachers in the department. Directors' support is needed to help participants disseminate knowledge, for example in dept. meetings.

Apart from facilitation of the participants' active participation by the department, their topics of interest were also discussed. In a kick-off meeting with all participants, they pitched their project ideas and got to know each other and the coaches and seminar lecturers. The seminars (2 initially), were focused on explaining the process of educational (design) research focused on improving teaching. Inspiration sessions, for example about 'flipping the classroom', were also organized. Sessions with the coaches, organized in groups of 4-5 participants, were aimed at motivation and more in-depth peer feedback on products from the participating teachers. The kick off

session, seminars, inspiration sessions and coach sessions were also aimed at building the SUTQ community.
At the end of the SUTQ track the participant is expected to deliver the following three products: (1) their own SUTQ product fitting with the educational question (article, design, advice, etc.), (2) poster of SUTQ results (See Figure 2) and (3) a reflection report. This is reviewed by a committee consisting of the participant's program director, a self-selected peer, and an educational expert. Apart from a review of the written products, a review meeting takes place as the final meeting.

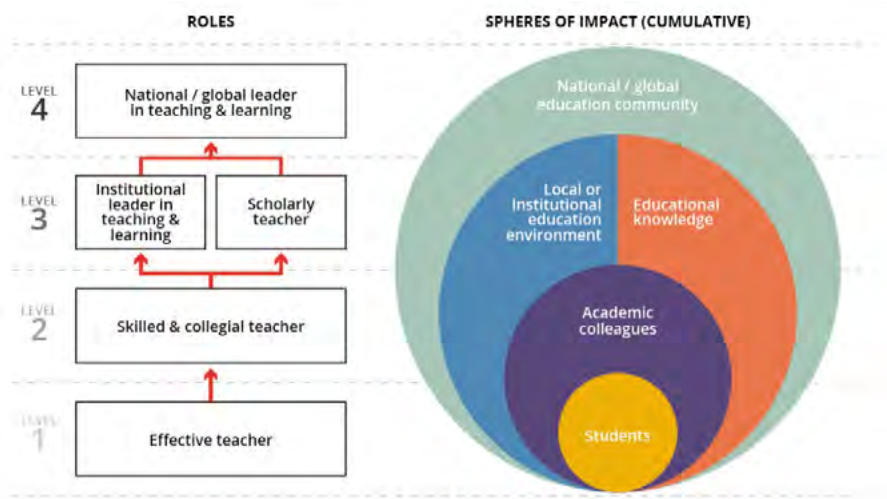

Fig.1 Career framework for university teaching [1].

2 OUTCOMES, EVALUATION AND ADAPTATION

2.1 Pilot program

The outcomes [3] in the pilot year showed that teachers worked on a large variety of themes, such as 'flipping the classroom', 'why do students plagiarize', 'serious games', and a 'hybrid test for mathematics'. Assumptions about their themes, such as flipping the classroom (are not automatically effective), motivation in serious gaming (is not automatically promoted), and student-centered learning (students with a hierarchical background do not have a less favorable opinion about SCL than other students) were often rejected. Participants learned more about their theme (e.g. 'wicked problems' in education); how to do (qualitative) research to innovate their teaching and how to adapt teaching based on data collection about their theme with students, such as amount of feedback and clarity of assignments.

Challenges were, for example, to actively involve colleagues, to conduct social science research with an engineering background, and integrating research design and course design (being able to experiment with an innovative course design and researching it at the same time). Participants were proud of achieving the planned

outcome (for example, a 'hybrid' test - partially open and partially closed, with reliability and validity comparable to paper and pencil tests; or taking on the challenge to critically reflect on teaching with help of student feedback).

The first evaluation of this pilot program showed three main elements of improvement: priority and facilitation in participants' departments (and, in relation, feasibility); opportunities to interact more with peers; complexity of the R&D seminars, where the focus was on research at the cost of designing for innovating teaching [3] and there was too little time to cover all relevant aspects sufficiently.

2.2 Second cohort

In the second run of the program, 15 teachers participated. The intake procedure was adapted in line with the pilot program evaluation results. Potential participants needed to fill out an application, including their motivation, and also needed to make a start with their research proposal already, to show both commitment and feasibility of their intended project (in their department).

We made two further major changes based on experiences and evaluation outcomes of the pilot (e.g., colleague involvement/priority at dept., conducting social science research and seminar complexity, integrating course and research design – i.e. also feasibility of the project; and interacting with peers).
Firstly, we extended the kick-off session from two hours to one-and-a-half days, in which participants did not only have the opportunity to get to know each other and the coaches and lecturers better, but also to work further on their research proposal, with help of the coaches and lecturers. Involving directors of education in the former intake procedure was replaced by inviting them to part of the kick-off session.
We also decided to implement a 'go/no go' procedure, to encourage participants to think through their research early enough to enhance feasibility of their project. Participants needed to submit their research proposal six weeks after the kick-off session to be reviewed by one of the coaches and one of the seminar lecturers, to ensure all participants would have a complete and well-structured proposal before data collection. Before the end of this six-week period the first seminar had already taken place (three weeks after the kick-off session), to make sure participants had received more input and feedback before the go-no go moment. In terms of peer interaction, we implemented explicit peer feedback and discussion moments within the kick-off session, seminars and in the meetings with the group coaches.

Regarding the seminars, we decided to cover part of the seminar content in the (extended) kick-off meeting already, to support participants in developing their problem statement, research questions and theoretical framework early on. The next two seminars were planned a month and four months later to go into design and data analysis, and evaluation and communication of the project. Writing sessions were

added for participants to be able to receive more just-in-time feedback of the coaches and seminar lecturers in a later stage.

The outcomes [4] of the second cohort again show a variety of themes, such as enhancing intercultural sensitivity, flipped micro lectures, and entrepreneurship, but also several student-driven learning sub themes, such as tailoring personal student paths.
Several participants noted how they became more aware of explicit teaching assumptions and strategies as an outcome of SUTQ, e.g., from “I did many things on my gut feeling” and “previously, I always used my intuition in ideas about educational improvements” to “I have learnt a lot about the fundamental nature of learning processes (…) the educational literature (…) to integrate classic engineering topics …with ideas about teaching”. Participants also mentioned student diversity (in background, prior knowledge, expectations) and positive student engagement as something they became much more aware of.
Although finding time to spend on SUTQ was still noted as a challenge by several participants, interestingly most participants mentioned the value and appreciation of being able to discuss and further develop their teaching with input both from students and colleagues (at their department) within the SUTQ framework, e.g.: “many colleagues and students were interested in my SUTQ topic and liked to contribute to it”. Several participants also mentioned being proud of becoming part of a community presenting and discussing research into education more confidently. Several have (started to) publish(ed) their SUTQ report as a paper in peer-reviewed journals, and/or have submitted or already presented at (engineering) education conferences.

Constraining the boundaries of their study, again in relation to finding time, was a challenge for some participants again, although some mentioned that the clear structure and timelines of the program helped in this respect. Run time was confining for some participants, not allowing the opportunity to collect data in each possible teaching quartile. For some participants particular social science research activities were mentioned as the biggest challenge they experienced, e.g. doing a focus group and “I have never coded and analyzed transcripts before”.
Apart from intermediate evaluations focusing on strong points and aspects for improvement by the program coordinators, the program was also evaluated by a Master student [5]. The goal was to formatively evaluate SUTQ, to identify further potential areas for improvement, focused on alignment of the SUTQ program with the institutional context and participants’ needs. This study employed multiple qualitative research methods including document analysis, interviews and a focus group session. Main outcomes of the evaluation where focused on the research approach, differences in prior knowledge, feasibility, and community building. Regarding the research approach, some of the participants had not expected a focus on educational research and had expected the content to be more about pedagogical strategies and/or accreditation issues. Prior knowledge of the

participants (and their perception thereof) in terms of social science research background was very different.

Regarding feasibility, the start- and end date and run time of the program did not offer the opportunity to study and implement in each possible quartile, although the idea is that participants are allowed to select the module that is the subject of their trajectory themselves. Regarding community building, both the participants and coordinators did not feel that the participants developed into a real community during the program. Although the participants appreciated more interaction with peers in coach- and other meetings, the participants did not feel that the entire group had sufficiently developed into a community.

2.3 Third cohort

We have made three main adaptations to the program for the third cohort, in line with (evaluation) outcomes in the second cohort:

1) Clearer design and communication of the research approach to (potential) participants already before the start of the program, adopting the research-informed teaching approach (RITP) [6], with more attention for a diversity in prior knowledge in terms of social science research knowledge and skills.
2) Extended run time (November 2019-April 2021) with more flexibility in start and end of the programme, to allow for data collection in the module and quartile of participants' choice.
3) Also connected to 1), Focus on particular themes to be able to form 'research learning communities' (RLCs) of participants for peer interaction and feedback purposes, aiming also to develop the community as a whole. These themes were: Student-Driven Learning, and Assessment for Learning, and still an open theme where we anticipated to be able to connect participants in RLCs based on commonalities.

Moreover, although the more strict intake and the go/no go procedure of the second cohort appeared to promote feasibility of participants' projects in the long run, it was experienced as a particularly stressful procedure in an already high workload context. Our main goal was to help participants consider the feasibility of their project early on, by making sure they aimed for a worthwhile research question and would have related data available (at the time of the study). We therefore asked participants to prepare a theme, a description of the problem they aimed to focus on, potential data collection, and give at least two scientific references supporting their idea, in their registration.
From the start, participants worked on a 'project plan worksheet' focused on theme, context, key literature and concepts, data collection and analysis, design, and planning in the first three months, receiving input and (general) feedback in the

seminars. After three months, someone from the Centre of Expertise in Learning and Teaching who was not one of the coaches, formatively assessed the project plan worksheets and provided feedback and suggestions to improve.

The program was started again with a kick-off meeting (where educational directors were invited too) of a full day with an introduction about the program, a presentation of a previous SUTQ participant, and a lot of attention for goals and expectations, also discussing these with participants. We explained our idea of RITP and let the participants themselves form their RLC's following a 'speed date' based on their theme and project ideas. After having explained the steps of the RITP approach adapted from [6]: 1) Analysis of context and problem in relation to student need; 2) Designing and developing the innovation; 3) Evaluation and refining the innovation; and 4) Reflection, a substantial part of the afternoon was spent on working in the RLC's with the coaches to discuss the way of working together, share literature en discuss themes and further specification of the project idea. The afternoon was concluded with each participant pitching their refined project ideas. Participants were also asked to continue working on their project plan worksheet and submit it before the next seminar, to be able to adapt this seminar to their needs (connecting better to their prior knowledge). In total, four seminars (again from afternoon until 8 pm, including dinner) were planned, each going into the theory of the next step of the RITP approach in the first part. There was time schedulre for working on participants' own project plan worksheets both with peers and individually after dinner – with feedback from the coaches and seminar lecturers to tailor for specific needs and questions.

Intermediate evaluation results of this third cohort, based on their project plan worksheets (their outcomes so far and the questions about what they have learnt and what suggestions for program improvement they have) and an evaluation meeting with coaches and one of the seminar lecturers, show that clarity and feedback in most of the meetings (kick- off and seminars) are mentioned as strong points by most of the participants, e.g. "Kick-off meeting was very good and inspiring"; "The meetings that I participated in were useful"; and "Keep up the good work in the lectures & feedback sessions.". Remaining challenges according to these results, were:

1) Distinguishing planned intervention and the actual problem this intervention is supposed to solve is challenging. Participants seem to find it easier to think of an intervention than to describe a problem relating to student need with their module. Concepts related to the problem (e.g. student self-efficacy or autonomy) are not yet always defined well. There was a lot of attention for defining the problem well in the seminars, however. The seminar lecturers noticed that participants usually started out with a lot of motivation and energy in the seminars, but after dinner this was substantially reduced.

2) Participants did not take a lot of initiative in meeting and discussing with the peers in their RLCs. The coaches feel that the community aspect of the groups and the whole group of participants could still be developed better.

3) Suggestions for improvement by the participants are varied. Some mention again how hard it is to find the time, e.g. "My biggest problem is to find time for this preparatory phase"; and that the curriculum for the program is hard given their workload at the time of the sessions. Some mention a slight lack of connection between the project plan worksheet and the seminars, and some do not find the evaluation criteria sufficiently clear.

Fig.2 SUTQ poster presentations.

3 CONCLUSION AND DISCUSSION

In the third year of running the SUTQ program, the content and approach of the program itself are largely to the satisfaction of the participants and organizers. Alignment of the intake phase, the kick-off meeting and the subsequent seminars could still be improved, however. In relation, the issue of defining a clear problem, supported by an analysis of the context and student need, also based on data, still requires more attention. Furthermore, although participants have mentioned the

importance of peer interaction feedback in each of the cohorts, and we have adapted the third year approach to cater for this even more extensively, we still think the community aspect of the RLCs and the group as a whole needs improvement. And thirdly, allocation of time is still mentioned as a difficult aspect.

These challenges also need to be considered from the policy perspective. Teachers need to be supported in their professional development aimed at achieving the ambitious goals of student-driven engineering education. At the same time, recognizing and rewarding teaching is essential to support effective professional development. The SUTQ program is in its third year and participants are very enthusiastic and have shown impact on their thinking, teaching approach and students. Policy and practice for recognizing and rewarding teaching is still lagging behind, however. At the university level, it is important that recognizing and rewarding teaching is formally organized and practically realizable. Decisions have been made but not yet implemented. This needs to be an active (and interactive) process at the different management levels [7]. Specifically, at the department level as well, attention for facilitation in time and resources to participate in SUTQ, and other professional development activities focused on research-informed teaching practice still need attention. This also applies to developing a teaching community. This is partly due to the fact that staff is organized in research capacity groups. To support teachers to participate given their busy teaching schedule, for example, the seminars are scheduled from late afternoon, including dinner and the evening after dinner. Participants value being offered dinner very much, yet the question is, how much active participation can be expected in the evening after a full teaching day? And even in this situation, teachers sometimes do not have the opportunity to participate because of teaching obligations. We are expecting senior teachers to develop themselves in terms of researching and designing their own teaching, while they have a high (teaching) workload at the same time. If we really believe SUTQ has priority, should participants not have the opportunity to spend time on it during normal working hours rather than mostly in extra time? This is a difficult discussion, but one worth having if we aim to take the innovation of engineering education in a research-informed way to the next level.

4 ACKNOWLEDGMENTS

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A NEW STATE OF THE ART MICROGRID LABORATORY SETUP FOR REMOTE, FLEXIBLE, HANDS-ON, EXPERIMENTATION IN POWER SYSTEM ENGINEERING

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***Conference Key Areas**: Future engineering skills and talent management; Niche & novel engineering education topics*
***Keywords**: Remote experimentation; Flexible learning; Blended learning; Collaborative learning, Power engineering education*

ABSTRACT

A brand new, state-of-the-art Microgrid Laboratory Setup was built at the Technical University of Denmark's (DTU) Ballerup campus to aid with practical, hands-on teaching in the field of power system engineering. The primary focus of the Microgrid Setup is to closely emulate the behaviour of thermal power plants, e.g. emergency power plants, modern distributed combined cycle gas turbine (CCGT) and combined heat and power (CHP) plants, especially with regard to synchronous generator control.

During the COVID-19 pandemic, an additional requirement came to the fore, in that this Microgrid Setup should also be fully accessible via the web. The design was broadened to include remote, hands-on and flexible experimentation [1], in order for student groups to engage in remote collaborative learning [2].

1 INTRODUCTION

1.1 The next generation power engineer

There has been a gradual shift from a small number of large power stations to a large number of smaller, distributed power plants in the recent year [3], [4]. The next generation power engineer [5] should not only have a detailed knowledge of the operation of the synchronous generators of these CCGT and CHP plants, but also on the operation of the typical state-of-the-art digital control equipment, different network protocols, supervisory control and data acquisition (SCADA) interfaces, etc.

The complexity in power system engineering has grown through the years [6], so that the next generation power engineer needs to become a "multi-disciplinary electrical engineer". He/she is required to have a detail knowledge that ranges from electrical machines (including how the CCGT and CHP plants work), power electronics, power systems, grid stability, programming, digital networking and

protocols, telecommunication, control systems, to “legislative” knowledge of the Grid Code requirements [7].

1.2 The Microgrid Setup specifications

When the idea of a new Microgrid Setup at DTU first took shape, a literature study was first done on similar laboratories in existence [8], [9], and [10]. The next step was to try and see how a laboratory like this could best compliment the majority of power engineering courses at undergraduate level. The vast amount of microgrid laboratories focuses primarily on the integration of renewables, e.g. solar, wind as well as the inclusion of storage, either using batteries of fuel cells. These topics are however more specialised and assume a basic understanding of the operation of the “traditional” grid.

It was decided that the Microgrid Setup, as a starting point, should be more like a “micro” version of the “traditional” grid, in order to focus on the fundamental topics of power engineering, with undergraduate students the primary target group. These fundamental topics should include: synchronous machine excitation characteristics, synchronisation with the grid, automatic voltage regulation, the effect the load has on the frequency of the grid, how to control the amount of generated power using frequency droop control, the effect reactive power has on the voltage, voltage regulation by changing the excitation of the synchronous generator, the effect inertia have on the frequency, and the list goes on. It is also paramount that the Microgrid Setup should be fully digitally operated, with a digital network interface, emulating real world implementations and use the latest state-of-the-art technology available [5].

Denmark has seen a steady increase in the amount of smaller CCGT and CHP plants in the last few years, [4]. For Denmark’s transition toward a renewable energy future, these plants need to fulfil a somewhat different role than with traditional thermal power plants [11]. It is also of vital importance that power engineering students understand the traditional generation principles in order to fully appreciate the complexity of modern power system with a large amount of renewable penetration. E.g. droop control of power electronic frontends for renewables wind or solar installation, the need for virtual inertia, or short term energy storage etc. would then make much more sense.

2 METHODOLOGY

2.1 Bottom up design of the Microgrid Setup

The whole idea of the Microgrid Setup centred around three old København Titan motor-generator (MG) sets that was found in the university’s basement – two of them with flywheels attached – which was destined to be scrapped. These MG sets made use of shunt DC motors from the late 1960s. We decided to scrap only the shunt DC

motors and replace them with three-phase induction motors, whilst still keeping the old three-phase, salient four pole synchronous generators, as shown in Figure 1.

Figure 1 – The three old (red) three-phase synchronous machines connect to three new (blue) three-phase induction machines.

With the prime focus of emulating a microgrid with diesel – or CCGT "power plants", this could be "easily" be done as in [12], using three-phase induction machines as prime movers, together with programmable logic controllers (PLCs) controlling three-phase frequency converters. This would create a more flexible experimental resource, ideally suited for flexible engineering education, [2]. The task of creating a diesel – or CCGT emulator, would also make for an interesting, even possibly a yearly recurring, collaborative design-built project.

The next step was to decide how these synchronous machines or "power plants" should be connected together to allow for maximum flexibility. A schematic diagram of how the experimental Microgrid Setup was configured, is shown in Figure 2.

Control cabinet +A1 (blue dashed rectangle) is responsible for connecting all of the synchronous machines together and if required, also to an external grid, or "infinite bus". For later expansion, control cabinet +A1 would also be responsible for the connection of solar and/or wind power emulators to the Microgrid. Room in the cabinet has also been reserved for equivalent pi (π)-models for the transmission line or cabling between the synchronous machines' – and the external grid's busbars, as can be seen in Figure 3 (a).

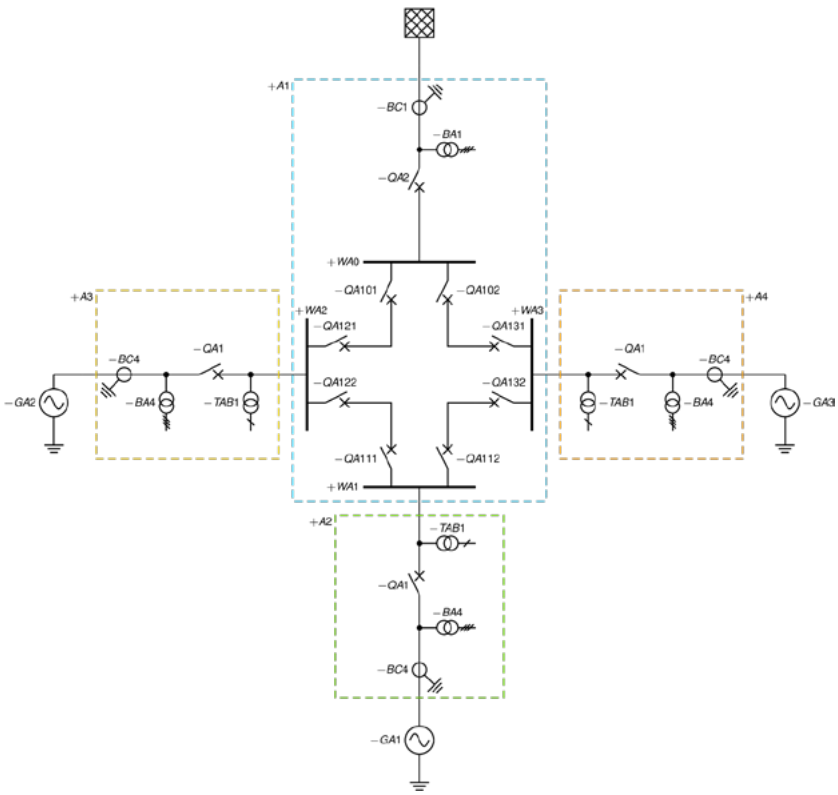


Figure 2 – Schematic diagram of the experimental Microgrid Setup.

Control panels +A2…4 (the other three dashed rectangles) are used for the control equipment for each synchronous machine. In order to increase the flexibility of the microgrid, it was decided to equip these control cabinets with a bi-directional ABB ACS800 inverter (as two 11 kW units were aready available) to drive the three-phase inductions machines. This would make it possible for the three-phase synchronous machines to work either as generators, or as motors. The 50% over size is ideal for fast ramp-up and ramp-down times. The layout of control cabinets +A2…4 is shown in Figure 3 (b), with the bi-directional inverter shown in the middle, left of the picture.

The advantage of having a synchronous machine operating as a motor, is that it is very easy to change the power factor (PF) at which the motor is operating. The motor can thus even operate at a leading PF. Also, by having one synchronous machine operating as a motor, and the other two as generators, the effect of increasing or decreasing the electrical load in the grid, and how this increase or decrease of generated power is shared by the connected synchronous generators (when not connected to the infinite bus), can easy be demonstrated. Different frequency-droop characteristics can thus be implemented in order to study the effect of load sharing, and/or frequency restoration in the grid.

(a) **(b)**

Figure 3 – (a) Control cabinet +A1 **(b)** Control cabinets +A2…4.

2.2 State-of-the-Art Synchronous Machine Excitation System

In order to ensure that the Microgrid Setup makes use of the latest state-of-the-art, small distributed power plant technology, we called upon the expertise of Burmeister & Wain Scandinavian Contractors A/S (BWSC). They have commissioned more than 180 power plants to 54 countries worldwide, with the latest power plant, the 56 MW North Power Station in Bermuda, which was handed over in a virtual certificate signing, due to COVID-19, on 31 March 2020, see Figure 4.

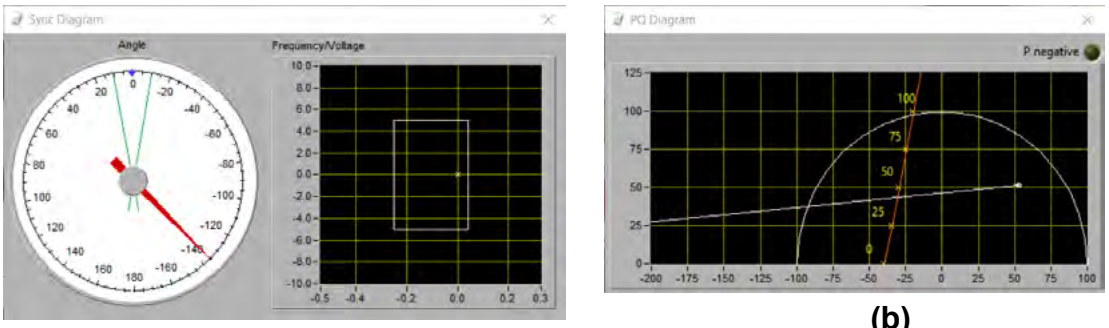
For the Microgrid Setup is was decided to make use of the ABB Unitrol 1020 excitation system[1], exactly the same as was used in the North Power Station. The Unitrol 1020 includes, among others, a built-in Automatic Voltage Regulator (AVR), a Constant Power Factor (PF) control mode, a constant reactive power or VAr (volt-ampere reactive) control mode, automatic synchronisation, black-start or dead-bus synchronisation as well as a fully functional IEEE Std. 421.5-1995 type 2A/2B/2C Power System Stabiliser (PSS). With the PSS functionally, the Microgrid Setup could thus be used to supplement courses in Power System Stability, where it should be able to demonstrate local/inter-plant mode oscillations (in the 1 to 2 Hz range) and remote/inter-area mode oscillations (in the 0.2 to 0.8 Hz – with sufficient impedances between the generator busses) in the power system.

[1] https://new.abb.com/power-electronics/excitation-and-synchronization/Unitrol-excitation-systems

Figure 4 – BWSC's North Power Station project in Bermuda[2].

The deciding factor however, was the CMT1000 LabVIEW based configuration and monitoring software program provided by ABB. This software is primarily meant to be used to configure ABB Unitrol 10xx excitation systems during commissioning. The CMT1000 software provides excellent blended learning opportunities [13] not only to supplement teaching in power systems courses but also in control systems courses, as well as for teaching Modbus TCP network communication.

For power engineering students the CMT1000 software provides a virtual software synchroscope functionality as shown in Figure 5 (a). It is also able to show the operation point of the synchronous machine on the PQ capability diagram, as is shown in Figure 5 (b).



(a) (b)

Figure 5 – (a) The ABB CMT1000 virtual software synchroscope (b) Operation point on the PQ capability diagram.

It is furthermore vital that power engineering students should be very familiar with MAC addresses, IP addresses, Subnet masks, Gateways, NTP server, etc. They also need to be familiar with the programming of digital network interfaces

[2] https://www.bwsc.com/media/press-releases/2020/north-power-station-toc

equipment. The Unitrol 1020 has a Modbus TCP interface which is one of the easiest protocols to implement from first principles on a PLC in one of the IEC 61131-3 languages, e.g. Structured Text. The CMT1000 software is able to display Modbus register data, Modbus request for a specific registers, together with the Modbus function codes, and the data transmitted.

When teaching control systems to power engineering students, there is usually a limited number of practical control systems experiments available, specifically applicable to power systems. Most control systems experiments are thus either simple motor control or power electronic related. The ABB Unitrol 1020 for the Microgrid Setup, enables the power engineering students to adjust the proportional (P), integral (I) and derivative (D) parameters for a PID regulated AVR controller. The CMT1000 software even has a built-in AVR Tuning Assistant to help with the tuning of the PID parameters. The graphical user interface (GUI) to some of these features are shown in Figure 7.

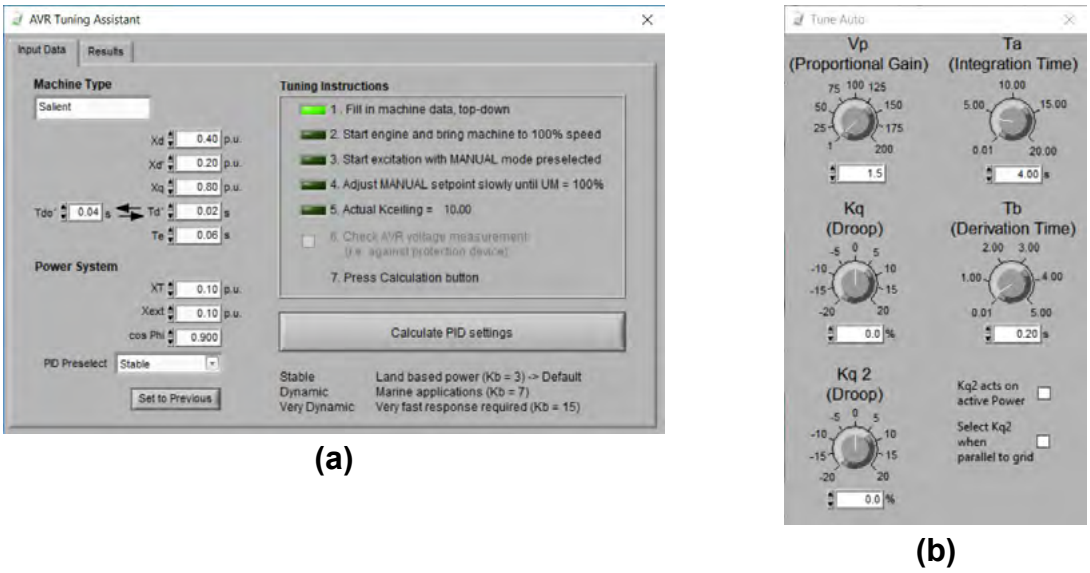


Figure 6 – (a) The CMT1000 interface for the AVR Tuning Assistant (b) Manual PID tuning interface for the AVR/Auto mode.

2.3 Microgrid HMI/Web-Interface

Each control cabinet were fitted with touch-panel human machine interface (HMI). For control cabinet +A1, the HMI would be used to control the connection configuration of the Microgrid and also control whether the Microgrid is connected to an external grid, or whether it is operational in islanding mode. The HMIs for control cabinets +A2…4 should controls the frequency converter which in turn control the speed and/or torque reference for the induction machine, thereby controlling whether the induction machine operate as prime mover or as three-phase generator/load.

The HMIs for control cabinets +A2…4 should also have full control of the excitation of the three-phase synchronous machine, by means of the ABB Unitrols. The DC field excitation should be manually adjustable, but it must also be possible to place the Unitrols in Auto/AVR mode, or constant PF mode, or constant VAr mode. It should also be possible to control the synchronisation of the synchronous machine to the rest of the grid, either manually or automatically using the Unitrols' built-in Auto Synchronisation Mode.

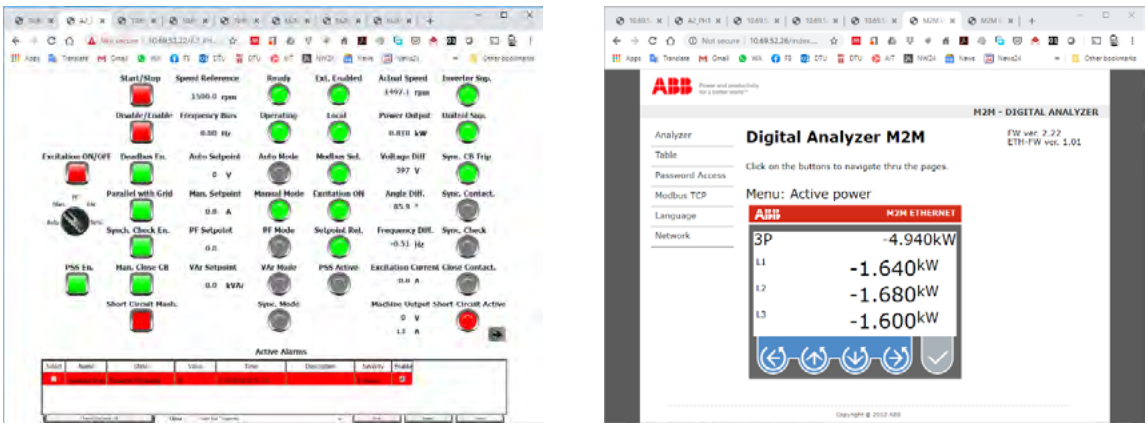
It was decided to make use of an ABB AC500-eCo PM556 PLC together with an ABB CP600 10" touch-panel for each control cabinet. These Linux based touch-panels have excellent user security features which limits access to different touch-panel screens/pages. This implies that different user names, e.g. "experiment1", "experiment2", etc. can be created that only grants access to the touch-panel screens/pages applicable to a specific screen that applies to e.g. a specific experiment. The CP600 also allows users access to web pages from a remote web browser running on either a computer, or a mobile device such as a tablet or smart phone. These web pages are HTML5 based which implies that no plug-in external software is needed to display information remotely.

The layout of the four control cabinets with the four touch-control panels is shown in Figure 8, whilst a web page running on one of the CP600's web servers, accessed via Google Chrome is shown in Figure 9 (a). The CP600 control panels also has built-in Alarm Tables that can be displayed either on the touch-panel, or on a configured web interface.

Figure 7 – The four control cabinets +A1...4 for the Microgrid Setup showing the ABB CP600 touch-panel and ABB M2M Digital Analysers.

Figure 9 (b) shows the web page interface to one of the ABB M2M Digital Analysers used. The M2M allows for voltage, current, active- and reactive power, apparent power, power factor, THD%, etc. to be measured. The M2M also has a very handy

'Table' option where all the measurements, for each phase, can be displayed in table form via the web interface.



(a) (b)

Figure 8 – Graphical User Interface (GUI) via a web browser for the touch-panel (a) and the digital power analyser (b)

In general, to quote from [2], "Remote monitoring, testing, and control are becoming increasingly important in manufacturing, process control, and customer support." The web-interface of the Microgrid Setup not only support this subject matter, but also makes it possible for Web-based experimentation to supplement the theory with practical, hands-on activities in engineering education.

3 RESULTS

Although the Microgrid Setup has not yet implemented all the intended specifications as mentioned above, it was still possible to perform a range of remote, hands-on, lab experiments during the COVID-19 lockdown period. For the course 62761 – Power Engineering II, the class was divided into seven groups, and the remote experiments was performed in three separate sessions to accommodate all seven groups. Detailed instructions on how to operate the web interface to the CP600 control panel and M2M power meters, as well as the extent of the experiments to be performed was distributed to the students beforehand, as well as briefly demonstrated in a Microsoft Teams on-line lecture.

Each of the on-line Microsoft Teams lab sessions started where all the groups (a maximum of three at a time) were given a re-cap of the operating instructions for the on-line interface, as well as the various on-line experiments to be performed. The groups where then split into three sub Teams meetings. The instructor were able to remotely monitor the different groups' control panels and M2M power meters continuously on his second 21" monitor. If he observed that one group was struggling, he could pop into their sub-meeting to clear up the problem, whether the issue was with the web-interface, or with some fundamental theory. The groups

could also use Teams Chat function to send the instructor a question, or ask him to join their sub Teams meeting, in order to explain something for them.

If the instructor saw that there was a common mistake, he could ask all groups to go to go to the main Teams meeting, while putting their sub Teams meetings on hold, where the common problem could be discussed. The instructor also cyclically popped into each sub meeting to comment on each groups progress, point out some interesting observations, etc. Although it was possible for the instructor to override some controls from his side, it never was necessary.

For this first remote, hands-on experimentation, the following online experiments were performed: (a) determine the open and short-circuit magnetisation curves of the synchronous machines; (b) synchronise the synchronous machine with the infinite bus; once synchronised, (c) operate the synchronous machine as synchronous condenser and a synchronous “reactor”; (d) operate the synchronous machine as an under excited and an over excited motor; and finally, (e) operate the synchronous machine as a under excited and over excited generator.

For each of these experiments, a number of current, voltage, power, etc. measurements needed to be documented, for use in additional calculations for the lab report. In the lab report the groups had to determine the saturated and un-saturated q-axis synchronous reactances. As it was impossible to measure the d-axis synchronous reactance online, this reactance value was given as a percentage of the q-axis reactance. With the q- and d-axes reactances calculated, the groups had to draw the six phasor diagrams for six different operating conditions, calculate the internal induced excitation voltage and power angle, and verify their active- and reactive power measurements with calculated values from their phasor diagram values for each operating mode.

From the seven groups, five groups scored above average grades (between 10 and 12 on the Danish scoring system), whilst two groups scored a 2 (just pass). This low score was not as a result of the on-line measurements, but had to with a fundamental misunderstanding of line-to-line, and line-to-ground measurements, as well as how to draw the phasor diagram of a salient-pole synchronous machine.

In general, the feedback from the students where quite positive, with the only comment from them that it would have been nice to have seen and heard the machines whilst doing the experiments. It was subsequently found that the CP600 touch panels has built-in support for a number of web cameras. Initial testing with a D-Link DCS-932LB web camera has shown promising results for video only integration into the CP600 touch panels and web server interface. In order to access the audio capabilities however, the web camera have to be accessed via the legacy Internet Explorer however.

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TRANSFER OF GAME DEVELOPMENT KNOWLEDGE INTO THE DESIGN OF A MIXED REALITY GAME FOR ENGINEERING EDUCATION

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Conference Key Areas*: Future Engineering Skills and talent management, e-learning, open and online learning, blended learning, virtual reality*
Keywords*: mixed reality, engineering education, digitalization, game-based learning*

ABSTRACT

Numbers of engineering students have continuously increased in recent decades. Didactic discourses in engineering education are strongly focused on competence-oriented, project- and experience-based learning. Due to the limited practical experience of first-year students, there are different levels of previous knowledge and a low student motivation for contents like management competencies and methodic skills. A game-based approach was chosen to teach those topics to first semester students. But how to develop an educating game for large student numbers which ensures the achievement of the learning outcomes and conveys the missing pracitical exprieriences while having fun with the gameplay mechanics? Therefore the game "FutureING" was designed in an interdisciplinary team of engineers, game developers and communication scientists. The Mixed Reality Game combines augmented and virtual reality, presence and e-learning modules. Management, methodical and technical

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competencies are linked and implemented in practical project work. The game conception and design considers learnings from the interactive entertainment industry in order to ensure a motivating game play and a high educational value at the same time. The paper focusses on the transfer of gaming knowledge into the educational mixed reality game, shows the methods and design of the first playtests and gives an outlook on the game implementation in the engineering curriculum.

1 INTRODUCTION

Soft and methodic skills are an essential part of the engineering curriculum as the trend to competence-oriented, project- and experience-based learning in higher education initially demands for those skills. At large universities of applied sciences in Germany e.g. each winter semester cohorts of 850 engineering students from five different engineering disciplines are trained in the fields of communication, project management and team work (teaching module working techniques and project organisation) [1]. To tackle the challenge of teaching these skills in a practice-oriented and comprehensible way a game-based and experiential learning approach is utilized. The learning outcome of the Mixed Reality Game is as follows: The students are able to implement context-appropriate working techniques and project organisation forms. They are able to analyse project situations with the essential factors of project evaluation, remember different organisational moods and apply the appropriate learning, communication and work strategies as well as scientific approaches in order to be able to design and implement sustainable, complicated and complex specialist projects with scientific demands. To realise this, the mixed reality game “FutureING” consists of four modules which are connected to the learning outcome.

Fig. 1. Modules of FutureING

The “FutureING” e-learning module (TrainING Center) is used as knowledge resource for the students and provides video lecture for the topics like classic and agile project management, scientific working, team work and team development. Furthermore, technical specifications (e.g. industry 4.0 concepts) and information about problem-solving methodology are provided to empower the students to solve the tasks in an engineer kind of manner. To prove their gained knowledge online tests are provided.

The presence module is an integrative “lesson learned” part after each game module and is executed together with special trained coaches.
The students will be guided to reflect their behaviour and decision making. They will identify quality patterns e.g. in team work, communication and problem-solving methodology which are essential for the success of their team.
The overall concept of the game entails the students working together in consulting engineer teams which work on different tasks. The teams will get two main tasks: The first one is to create and optimize a new shop floor for a robotics company (AR module) with industry 4.0 technologies. In the second task the new shop floor is in operation and shows that the industry 4.0 production has to be optimized in some areas of the production chain (VR module). Withing FutureING the students apply management, methodical and technical knowledge in various situations and settings e.g. planning the production hall with a simulation. They become familiar with modern automation technologies, work on the state-of-the-art and achieve "budgets" for their projects to reach the next level. With the game-based learning approach of FutureING the students will be motivated to train and experience the level of their skills. The following section shows an approach for the development of an educational game for large classes which ensures the achievement of the learning outcomes and conveys the missing pracitical exprieriences while having fun with the gameplay mechanics.

2 LINKING OF IMMERSION, REFLECTION AND GAME MECHANICS AS METHODOLOGIC BASIS OF EDUCATING MIXED REALITY GAMES

2.1 Immersion and Refection within FutureING

Mixed Reality Games are particularly suitable for experience-based, immersive and reflexive learning contexts, since the consequences of playing them give the players immediate feedback on their actions - an "actio et reactio" experience is conveyed [2]. Another advantage is that this game concept can be scaled for a large number of listeners. Immersion refers to the process of defrosting into another world and forgetting time and space in reality. The more you immerse into the other world with all your senses, the more intense and lasting the experience. Strong audiovisual impressions, a realistic and exciting plot and settings and identification figures that seem as real as possible are an important factor for immersive learning. Immersion thus supports intensive experience and a form of "being present" of its own, which provides a basis for reflective learning processes. The visual development plays an important role in defining the immersive setting and providing context to situate tasks. One aspect impacting the credibility of the project for the target group is in which way the game environment represents the real-world context and how it can be used to improve the learning experience for students. To enhance the acceptance of students the project is aimed at, the game modules display the actual working environment in the industry in a simplified, more accessible manner, while also showing futuristic influences of industry 4.0. Players can experience the 3D environment through animated assembly cells and driverless transport systems which ties together abstract planning methods and practical, visually represented results. All modules follow the general rule of

providing an approachable and understandable visual design, especially for the AR module it was important to focus on the construction kit-like aspect of the game and displaying this through clear, contextualized user interfaces and machine designs inspired by real manufacturers' products. This visual development approach ensures that students receive a realistic, credible view on modern working processes and gain insights into possible changes in the way collaborative robots influence regular procedures. In didactic discourses, reflexivity is regarded as an important meta-competence for enabling optimal learning processes [3] and is realised in presence sessions. While immersion and reflection are basic prerequisites to build and process learning experience of the MR game, the learning process and outcomes will be supported by game mechanics and empirical knowledge from the entertainment industry as the next methodological sections show.

2.2 The AR Module and Its Game Mechanics

To realize a scalable game, the decision for the setup of the AR Module began with an internal survey conducted among 307 engineering students implied that over a third of them are used to playing on mobile devices, while 305 of them stated, that they own a smartphone. Mobile-based AR promised to spark curiosity among students, due to its novelty. A tracker, would anchor the play space around a fixed point, a beneficial side effect in a communication focused multiplayer learning game. Within the AR game, students collaborate in teams of six to design a production chain, using assembly cells and automated guided vehicle systems. In order to meet contracts, each manufactured product needs to go through four steps of production. There are three different product sizes, and assembly cells are specialized in different sizes and production steps. Each contract specifies a budget and timeframe, as well as a production volume to be met. There are two roles in the AR module: Researching available machines, and arranging the machines. One player can purchase and place assembly cells and automated guided vehicles on the projected production floor. The other five players have access to a brochure, providing detailed information on the assembly cells and AGVs (Automated Guided Vehicle), unavailable to the first player.

Fig. 2. Screenshot AR Game

They can't however, purchase or place anything. Thus, communication and cooperation is needed. Once the players have set up their production chain, they can watch

the factory in motion, simulating the assembly of the necessary pieces. If they succeed to meet the production volume, they get a three-star rating based on their expenses.
Three game design concepts of the AR module are discussed in detail, as they were adapted from traditional ludic video games for their usefulness in an educational game. These mechanics allow for experimentation in a safe environment, reflection on one's approach, project management, communication and team work.
Providing different amounts of information and agency to players, playing collaboratively is a common practice in ludic multiplayer games, necessitating team play and communication. A recent example of a game completely centred around this dynamic is "Keep Talking and Nobody Explodes" [4], in which players need to disarm procedurally generated bombs, providing one player with the ability to do so, but no information how, and the other player only with a bomb-defusal handbook [4]. In his 2016 Game Developers Conference talk, Keep Talking and Nobody Explodes designer Ben Kane describes how the game was specifically designed around player conversations and collaborative decision-making [5]. Providing different amounts of information and agency to players, playing collaboratively is a common practice in ludic multiplayer games, necessitating team play and communication. Applying this dynamic to an educational-game to incentivize team play and communication in a practice-based learning and teaching environment seems definitely promising. And first playtests show its success in requiring players to communicate and actively collaborate.
A second concept adapted from traditional games, particularly for learning outcome is that of a delayed simulation-based on initial player input. This two-phase gameplay division asks players to use their current understanding of a system, hypothesize on the results of their input, then execute. In the second phase, they get to observe the results of their input, without or with limited ability to alter their input.
These phases are then repeated, until players achieve their goal by refining their understanding of the underlying systems. A classic example of a ludic game that utilizes this simulation-based gameplay split is famously "Angry Birds". Players need to slingshot birds into structures, in order to topple them, and eliminate the pigs inside. Players unknowingly need to make complex physical estimates about the slung birds' trajectories, their impact force at the structure, the structure's weak points, the different parts and materials of the structure any many more. They plan their shot, release the sling, and observe the ensuing destruction. Through short times between input and observation, players can quickly iterate, try out new approaches and methods and meanwhile improve their understanding of the game's physics system. [6]
This gameplay split seems to be a perfect match for use in an educational game, as it requires player observation and critical evaluation of one's previous attempts and allows players to form a model of a complex interacting system through play. This also means, however, that the quality of the learning outcome is largely dependent on the game system's accuracy and applicability to real systems.
An interesting challenge on this project was to abstract complex real-world systems into accessible gameplay for first semester students. Long interdependent real-world processes needed to be condensed, to still create a responsive game that reacts to player input, and affords a reasonable amount of iteration. The acquired player skills

still need to apply in the real world. Future exhaustive playtests on students will help in optimizing the game's mechanics for learning outcome.
The third game design concept used is a three-star rating at the end of each simulation, based on the quality of the players' approach. It is a common casual and puzzle game mechanic, for example, also used in "Angry Birds" [6]. It removes the binary of a typical win or lose statement, which makes the game more accessible and reinforces even early correct interactions with the game through positive feedback. Serving as a measurement achievement, it also allows players to reflect on their performance in comparison to their self-set goals, giving them a feeling of competence and increasing intrinsic motivation [7].
Iteration or second tries are encouraged, while the existence of a possible better solution is communicated through the star rating. Two of the six player types outlined by Nick Yee are likely to be additionally motivated through the use of this mechanic, players focusing on mastery of the game, and players focussed on achievement [8].

2.3 The VR Module and Its Game Mechanics

The second module is a multiplayer mixed reality VR game, asking players to service their previously created assembly line. Half of the students enter a VR production hall needing to detect and fix hardware - and software errors in a running factory. The other students have research and management tasks, played at a desktop PC or a desktop PC within VR or using an analog brochure.
The VR repair players, desktop players and brochure players will need to exchange information and tackle problems together to research, diagnose and fix the assembly cells. For example, the desktop players use their dynamic statistical information to point the repair players to potentially broken machines. The brochure players then can open the appropriate manual, as seen in "Keep Talking and Nobody Explodes" [4]. The repair players navigate the VR space (as seen in Fig. 3) and use diagnostic tools, for instance a voltmeter on the machines.

Fig.3. Screenshot Blockout VR Game

This way, players need to play through different production halls of increasing complexity, and are again given a star rating, dependent on the speed and quality of their problem solving.

Currently in the prototyping phase, a number of mechanics have already been layed out for the VR game, while more will yet emerge from the iterative development cycles. So far, the game takes advantage of the game design concepts of different amounts of information and star ratings outlined in the previous section. However, it embeds the two-phase simulation split within a continuously running game. Instead of player input and simulation being two long phases of play and observation, in the VR game, their cause and effect relationship becomes immediate. Action, observation and reflection stay at the core of this mechanic, but their frequency increases immensely. This altered mechanic tied to specific machines allows simultaneously occurring challenges, and lets players interact with them at the same time.
With a VR based teaching module, accessibility is an important concern, and has naturally influenced the game's fundamental design. Virtual Reality headsets are still causing motion sickness in a significant number of users, with a recent article on the Oculus Rift suggesting that under certain conditions over 50% of users could be affected, further implying a troubling gender-based difference in responses [9]. Thus, a Mixed-Reality approach with a non-VR-part is important when considering the accessibility of an educational VR game. The desktop roles can be played both in VR, and on a desktop PC, while the manuals can be opened or printed as PDF files anywhere.

3 CURRENT TESTING AND PRELIMINARY RESULTS

The AR module has been tested applying the framework for training evaluation as outlined by Kirkpatric [10], and its adaptation for the purposes of testing serious games by K. Emmerich and M. Bockholt [11]. The first playtests with engineers (n=8) focussed on the first two levels of evaluation: The level of reaction, checking the quality of game mechanics and aesthetics, and the level of learning, whether users understand the dynamics at play within the presented system [11]. Initially, open questions and criteria were defined, allowing the creation of a testable play situation and a test protocol. Given the early stage of development, a qualitative approach to the test was preferable. In order to gather both subjective and objective data, a two-phase questionnaire was created. Players played unobstructed, and their questions, comments and specified interactions were recorded. Then, they were asked particular questions, probing their fundamental understanding of the prototype, its rules, and their understanding of the underlying system. Further, users were asked to name enjoyable and unenjoyable parts of the play-experience. The described procedure allowed recording data on how users approach the game, unveiled qualitative areas with room for improvement and tested if users understood and could explain the underlying system represented in the game. The playtest data suggest, that users manage to understand, and explain the underlying system correctly, are able to accurately describe strategies for progression, and start experimenting with their new understanding after roughly 15 minutes of play. After their second planning phase, all testers managed to reach at least a one-star rating, while only one group reached a three-star rating after their second try. Generally, they observed the simulation phase carefully and were able to adapt their strategy accordingly. The testers enjoyed the setting and presentation. The social factor and

draw of a multiplayer AR were, stronger than expected, with non-testers quickly crowding around the testers, wanting to join the discussion or get a view of the organized production floor.
However, so far, only the learnability of the game's system has been tested. Further research and experiments need to be made on how students will translate game-knowledge into real-word applications thereof. Enabling them to do so, will require the system in the game, and the necessary player actions, to accurately portray and relate to real-world applications. Moreover, it needs to be clearly stated, that the playtest did not cover a large enough sample size, or an authentic enough sample, as it was done on engineering graduate students, as opposed to first-semester undergraduate students. The game is continuously improving and balancing and presentation are going to be honed to accomplish maximal real-world learning outcome. For now, the combination of ludic game mechanics, augmented reality and mixed reality applications shows engaging learning, practise and teaching potential. The results from the first rounds of playtests were used to optimize the game's accessibility, communication aspects, and the communication of its rules. A more representative playtest with engineering students was prepared for the beginning of April, but was unable to be performed, due to Covid-19 related closures of public institutions. This larger scale playtest expanded on the described formula, and shifted the focus to the second and third layers of Kirkpatrick's evaluation model of changed behaviour, learning and changed behaviour [10]. After playing, testers would have been asked to reflect on their social behaviour, and to judge, whether or not they think they learned something about engineering specific working, improved their project management and their ability to work in teams. Currently, an online multiplayer mode is being developed to allow players to test and play the game remotely.

4 SUMMARY AND OUTLOOK

In this paper the modules of the mixed reality game "FutureING" are described as one approach to bring soft skills and methodical knowledge to large classes of engineering students. In terms of constructive alignment, the competencies are assigned to the various learning modules. For this purpose, the levels of the corresponding actions are currently operationalised in the game by measuring the students' actions in the game and analysing in which level the competence was acquired by the students. The next steps for AR game are additional playtests with students and studies on what extend the learning outcomes are achieved. A first prototype of the VR game's underlying systems such as networked multiplayer, movement and repair tools has been made, and the project is expected to enter production in June 2020. Once a first completely playable version is made, playtests evaluating its learning outcomes and optimization can be made. The TrainING Center with online videos, tests, technical libraries etc. is already developed as an instance of the Ilias learning platform and currently used in combination with presence classroom simulations. The TrainING Center will be integrated into the game environment as soon as AR and VR modules are ready. The presence module for reflection and lessons learnt is already deployed and tested since the previous semester.

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TOWARDS MOBILE-CENTERED AUTHENTIC, PERSONALIZED AND COLLABORATIVE ASSIGNMENTS IN ENGINEERING EDUCATION

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ABSTRACT

The last decade has seen a significant rise in the use of mobiles devices, such as smartphones, tablets, or laptops in all areas of society. Professionally, engineers collaborate with partners all over the world and this is made possible by mobile technology. In tertiary education, students learn in different settings, in and out of campus, in the train or at a café. Researchers have identified new possibilities for teaching and learning, afforded by the use of mobile technologies (and termed 'mobile learning'; ML). They claim that ML may (1) facilitate learning, formally or informally, in a place, at a time, and in a way preferred by students, (2) help students to become engaged in tasks that resemble authentic tasks in the workplace, and (3) facilitate student cooperation and collaboration. In this paper we present the first results of an ongoing project which aims to design and evaluate – for different engineering disciplines – prototypical ML assignments. We report on the results of a survey carried out at a Dutch University on the current use of and attitudes towards ML from both the instructors' and the students' perspectives. The results show that in various faculties at the university ML initiatives have been introduced in education and that there is a basis to create further opportunities for active student learning. We also present an outlook on the next stage of the project: the design of prototypical student activities from the respective engineering disciplines of the project partners: Mathematics, Physics and Built-Environment.

1 INTRODUCTION

1.1 Mobile Learning and Authenticity

The use of mobile devices, such as smartphones, tablets, or laptops has been widespread in the private, professional, and educational areas of society. In developed societies, most members of the population routinely use mobile devices. For example, in 2018, 86% of the Dutch population used a mobile device to access the internet outside of home or the workplace, according to the national statistical office Statistics Netherlands (CBS); the European Union average was 69 percent [1]. Recent events have shown how mobile and online learning becomes vital when unexpected events such as lockdowns happen. In the last months teachers and lecturers across the globe have been faced with the immediate need to digitalise their teaching material and provide online resources for their students. Even before this rapid shift towards online education, researchers have identified new possibilities for teaching and learning, afforded by the use of mobile technologies. Mobile technologies may (1) facilitate learning, formally or informally, in a place, at a time, and in a way preferred by students, (2) help students to become engaged in tasks that resemble authentic tasks in the workplace, and (3) facilitate student cooperation and collaboration [2]. Mobile learning might also have negative effects, such as heavy cognitive load caused by an improper learning design [3].

The use of mobile devices in education has been termed ‘mobile learning’ (ML) or ‘m-learning’, defined by El-Hussein and Cronje [4] as ‘any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners and mobility of learning’ (p. 20). The definition emphasizes that ML is more than learning supported by mobile technology. Devices that fall under the umbrella of ML are for example mobile phones, tablets and modern laptops, which comply with the authenticity, personalisation and collaboration facets, allowing students to use them at a time and space (train, café, etc.) of their choice. Here, mobile phones and tablets are in focus because of their innovative use cases.

In this paper we present the first results of a survey carried out at a Dutch University of Technology on the current use of and attitudes towards ML from both the instructors’ and the students’ perspectives. The survey is part of an ongoing project started in 2019 entitled “Mobile learning for challenge-based education – Enhancing engineering education with mobile-centred authentic, personalized and collaborative assignments”. The project goals are to design and evaluate prototypical mobile-learning assignments in different engineering disciplines, which can be implemented in an authentic way through mobile technology.

To prepare the design of ML activities in different engineering disciplines, knowledge is needed about the current use of and attitudes towards ML. Hence, to better understand the current use of mobile technologies for learning, the following research questions were investigated:

RQ1: What are the attitudes, experiences, and ideas of university experts of the respective engineering disciplines regarding the use mobile technology in their teaching and in their research?

RQ2: How do students perceive the use of mobile technology for learning?

We first describe the analytical framework for ML, using the socio-cultural approach of the iPAC model (with PAC standing for Personalisation, Authenticity and Collaboration) and then present the results of the surveys.

1.2 Theoretical Background

The central tenet of ML is that it blurs the traditional time and space boundaries of traditional classroom learning (e.g. a fixed timetable and a specific classroom). As traditional time and space boundaries are dissolved, ML can be implemented at times convenient to the learner and in relevant (real or even virtual) contexts. Based on the socio-cultural notions that learning is situated, facilitated by social interaction, and mediated through the use of tools, this tenet led to a mobile learning framework [2] which illustrates the three central facets of mobile learning. The three distinctive facets of ML are authenticity, personalization and collaboration (Figure 1; [5]).

Figure 1 - iPAC framework [5]

Authentic learning activities utilize real-world situations and problems. In that way they allow students to develop competences in the context/s in which these competences will later be used. It has been argued that authentic learning is essential to make learning genuinely meaningful for the student, as all knowledge and skills derive their meaning from the authentic context [6]. In the iPAC framework, ML may foster authenticity through (a) the task (the extent to which it resembles tasks of real-world practitioners), (b) the setting (virtually or physically authentic), and (c) the digital tools used (resembling the tools used by real-world practitioners).

The *personalisation* facet of ML is subdivided into two related subscales: agency and customisation [2]. Agency refers to the level of control and ownership the learner has with respect to the learning process. This includes, for example, the possibility for

students to choose their own lines of inquiry, and follow their own interest [7]. Customization may take place at the tool level (i.e. personalisation of the mobile device, selection of tools) and at the task level (student control over the place, pace and time of learning). The personalization facet of ML fosters student autonomy, which under the right conditions may contribute to motivation [8].

Mobile technology facilitates interaction and *collaboration* as it enables students to contact peers, teachers, and experts, informally or supported/encouraged by the learning environment [9]. From a socio-cultural perspective, forms of interaction are essential for learning. ML facilitates interaction, as documents, sensor data, pictures and videos, and other resources can easily be shared through mobile connections, and be used by other learners. Accordingly, the collaboration feature of the ML framework distinguishes the subthemes conversation and data sharing [2].

The iPAC framework shows the potential of ML for learning. However, we do not know to what extent the actual use of mobile technology at our University allows this potential to be realized. Therefore we studied how mobile technology has been used by the university teachers for teaching and research, and by the students for learning, and what their attitudes towards mobile technologies in the context of learning and teaching are.

2 METHODOLOGY

To answer the research questions, we used the following data collection strategies:

2.1 A survey administered to all university teaching staff (RQ 1).

An email was sent to 1009 university staff involved in teaching (including professors, associate professors and PhD candidates who are involved in both teaching and research) with an invitation and a link to the survey. We received n=84 usable responses.

The core items of the survey asked respondents about their experiences and ideas related to the use of mobile technologies for research, engineering practice, and in the engineering education of their respective disciplines. Respondents also had the opportunity to state reservations they had regarding the use of mobile technology in education. A mobile device in the context of the surveys was a smartphone, tablet, smartwatch, or other general-purpose small portable device. We did not include laptops, as we expected them to be routinely used in research, engineering and learning. The survey consisted of 14 items.

Answers to the open survey items were (non-uniquely) coded, and the codes were categorized as ideas for: engineering practices and research (authentic practices); educational organization and enactment (personalization and collaboration); reservations on ML general comments.

2.2 Follow-up interviews with selected university teaching staff (RQ 1)

Selected participants from the university staff were interviewed. The selection of participants was made from the respondents who gave their email address in the survey. The selection was based on two criteria: (1) to involve different university departments, and (2) to select respondents whose survey responses provided specific ideas regarding ML. We contacted eight survey respondents from different departments, five of whom gave permission for an interview, from the departments of Applied Physics (also connected to Mechanical Engineering and Electrical Engineering), Chemical Engineering, Applied Mathematics, Electrical Engineering and Built Environment. In the interviews we asked in more detail about the present uses of mobile technologies in research, engineering practice and education, and about ideas for future use. The interviews were transcribed and coded to find current uses of mobile technology in research, engineering practice and learning at the university, and to find opportunities for ML that can be developed into a prototype.

2.3 A survey administered to all TU/e bachelor students (RQ2).

An email was sent to the TU/e bachelor students with an invitation and a link to the survey (6108 students). We received n=486 responses complete enough to be used in the analysis. The survey consisted of 14 items, with several sub-items, including: student background information; the Integrated Communications Technology Learning scales [ICTL; [10]]; the use of mobile technology for learning and for private matters.

In the analysis of the surveys we used descriptive statistics and coding of the open items.

3 RESULTS

3.1 University teaching staff survey and interviews

The survey results showed for which purposes in the field of research/engineering of the respondents mobile devices were more/less important. The majority of respondents considered mobile devices to some degree important to find information, to communicate, to collaborate, to make/share pictures, as well as audio/video recordings, and to use particular apps. The majority of respondents did not consider the use of mobile devices important for the purposes of dissemination (e.g. of research results), joint work on documents or designs, data collection (e.g. using mobile device sensors), using locally specific information (e.g. augmented reality) and virtual reality. We found differences between departments on the importance of mobile devices for particular purposes. For example, respondents of the department Built Environment considered the use of mobile devices generally more important for practice/research than members of the other departments. In particular this was the case for the purposes of data collection, obtaining locally specific information, and virtual reality. The departments of Mechanical Engineering and Electrical Engineering considered mobile technology less important, except for the purposes of “making pictures, videos and audio recordings”.

The university (associate) professors interviewed generally had a positive attitude towards the use of ML, as indicated by the following two citations:

"If students use their mobile anyway during lectures (…) you may just as well make sure they use it for the lecture", and
"There are advantages in bringing (student) projects from the lab closer to reality and I notice that the recent generation of students really likes that".

The responses to the teaching staff survey and the follow-up interviews resulted in a list of experiences and ideas on the use of mobile technologies for research, engineering practice, and in engineering education, as well as reservations regarding this use. A summary of the findings, categorized as "established", "emerging" and "reservations", is shown in Table 1. Established practices were those that have been encountered routinely in (tertiary) education. Emerging practices have been used by one or a few respondents (e.g. in research or practice), have not been used routinely in (tertiary) education, and required technical and/or educational development work. Be reminded, these responses reflect the situation before the Covid-19 lockdown.

Table 1. Summary of university teachers' experiences and ideas

	Established practices	**Emerging practices**	**Reservations**
Research	Documenting research work (journals, camera). Location-based services and information at the site of interest. Collaboration and communication.	Complex data collections about humans (mobility patterns). Various forms of data collection, e.g. using cheap sensors.	
Teaching	Accessing information. Submission of student work. Apps to make teaching more interactive. Collaboration and communication. Recording lectures.	Apps that allow to explore/simulate inaccessible phenomena. Integration with tools to replicate scientific practices. Interactive course materials. Student assessment. Tools to organize self-directed learning.	Lack of evidence about learning benefits in large scale studies. Distraction. Facilitate understanding, not and end in itself. Maintenance of infrastructure. Does not replace face-to-face interactions.

3.2 Student survey

The ICTL part of the survey contained a scale on *Information seeking*, a scale on *Information sharing* and a scale on *classroom learning* [11]. We did not use the classroom learning scale, due to its low reliability (Cronbach's alpha 0.43). The other scales showed acceptable reliabilities (Cronbach's alpha 0.66 and 0.77 respectively).

Table 2. Mean of ICTL scales (N=485)

Scale	**Mean (1-4)**	**SD**
Information seeking	3.26	0.49
Information sharing	2.54	0.65

Table 2 shows the mean values for the two scales. A comparison of the means indicates that students' attitudes towards online information seeking is more positive than towards information sharing (Related-Samples Wilcoxon Signed Rank Text, p=0.000).

To compare students with high and students with low scores on the ICTL items, a k-means cluster analysis with two clusters was conducted on the ICTL items in the "Information seeking" and "information sharing" scales (detailed in Table 3). We found a cluster of students with a relatively high mean ICTL score (indicating a positive attitude towards information seeking and information sharing; 54% of respondents) and a cluster with a relatively low mean ICTL score (indicating a less positive attitude, in particular towards information sharing; 46% of respondents). In the group with the positive attitude male students were overrepresented; students in this group on average used more mobile devices, used them more often, and used them more for study related activities than students in the group with the less positive attitude. We identified some differences between students from different departments (e.g. computer science respondents in majority belonged to the group with the positive attitude, while chemical engineering respondents in majority belonged to the group with the less positive attitude).

Table 3. Comparison of students with high (cluster 1) and low (cluster 2) mean ICTL scores

	Cluster	
	1. Higher ICTL	2. Lower ICTL
N	255 (54%)	221 (46%)
Information Seeking[a] (1-4); M (SD)	3.49 (0.37)	3.00 (0.47)
Information Sharing[a] (1-4); M (SD)	3.01 (0.43)	2.01 (0.40)
Male[c]	182 (59%)	128 (41%)
Female[c]	73 (45%)	91 (55%)
Estimated hours spent daily using a mobile device; M (SD)		
In own time[b]	3.0 (1.6)	2.7 (1.7)
At university for studies[b]	1.0 (1.0)	0.73 (0.85)
At university for private matters[b]	1.4 (1.3)	1.2 (0.9)
I use my mobile device to study		
Where I want[a] (1-4); M (SD)	3.1 [a] (1.0)	2.8 [a] (1.1)
When I want[a] (1-4); M (SD)	3.0 [a] (1.1)	2.7 [a] (1.1)
How I want[a] (1-4); M (SD)	3.3 [a] (0.9)	2.8 [a] (1.1)

Notes: [a]: p<0.01; [b]: p<0.05; independent samples t-test

[c]: There was a significant association between gender and cluster $\chi^2=8.70$, $p<0.01$. This indicates that, based on the odds ratio, the odds of being in cluster 1 is 1.77 times higher for male students than for female students.

We also asked students for examples on the use of mobile devices in university courses and non-exclusively categorized the responses. Table 4 shows how often students mentioned examples from the different categories. It highlights that the use of mobile devices for communication and the use of apps provided by the university are by far the most common used of mobile devices by students for their courses.

Table 4. Examples of student use of mobile devices for university courses

Category of use	**Percentage of students**
Communication (e.g. Whatsapp, email)	80.8%
Apps provided by the university	23.8%
Looking for web based information (e.g. Wikipedia) Collaboration on projects and group work Quizzes during lectures Course relevant videos and videolectures Calculators and maths apps	< 10%
Note taking / agenda / to do list Using course specific apps Share documents Take pictures / record videos Making use of buit-in sensors	< 5%

4 SUMMARY

We found that in various departments of the university ML initiatives have already been introduced in education. In particular, students have used mobile devices to access information, and teachers have used ML to make their lectures more interactive. The potential to develop ML could be found in the introduction of more authentic tasks and challenges and in more sophisticated ways to personalize the learning experience. In particular, some ML research practices identified in the study could be a foundation to design research-baed learning activities that utlize ML.

Our respondents do not constitute a representative sample of the university staff and students. Nevertheless, the attitudes of the TU/e staff and student respondents towards ML provide an solid foundation to start designing and testing ML tasks. The results suggest that in the design of ML learning activities one should take into account that there are reservations and that not all students shared the same positive attitude towards ML. Therefore, the added value of any ML learning activity for didactical and educational purposes needs to be transparent to both teachers and the students.

For the next steps of the project – developing and testing prototypes (2020-2021) – we have selected three use cases for further development from the ideas and suggestions we received. They will be developed, tested and evaluated in the following phases of the project. These cases are:

1. ML student preparation for a 3D virtual laser lab (Applied Physics);
2. Interactive mobile-optimized consolidation tasks on Linear Algebra (Applied Mathematics);
3. A mobile app in combination with student tasks to collect and analyze localized data (Built Environment).

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DECONSTRUCTING THE POST-GRADUATE PROJECT: TIME FOR CHANGE?

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ABSTRACT

Focusing on what is an almost universal facet of graduate level education, the 'Research Dissertation', this paper examines how students are prepared to conduct an independent piece of research in three areas of study associated with engineering or industrial management. Focusing on the provision of 'Study Skills and 'Research Methods' training, 62 UK universities were identified as offering courses in one or more of the following programme areas: MSc Engineering Management: MSc Supply Chain and / or Logistics Management: MSc Project and / or Operational Management. An analytical framework was developed and data collected.

This paper presents the data before discussing how one large engineering education department in the UK has completely reviewed and revamped how students are prepared for their dissertation. Attention is given to the pedagogic approach and academic content whilst the paper brings the issues up to date by briefly touching on how the students are being supported during the Covid19 Pandemic.

Keywords: Dissertation, Student Project, Study Skills, Graduate study

1. Introduction: Background on the Case Study Organisation

This paper discusses the preparatory work undertaken in renewing the way in which a large cohort of graduate students within one of the UK's largest engineering education faculties are supported in making the transition to a higher level of study and prepared for the 'cornerstone' of their postgraduate education: the MSc dissertation. Situated in a large Russell Group University, the faculty houses just under 1,500 postgraduate students studying a range of engineering and engineering related programmes. The majority of students are full-time and follow courses of study which lead to qualifications in Engineering Management, Supply Chain and / or Logistics Management: Project and / or Operations Management. All students are required to conduct an independent piece of research in the form of a MSc Dissertation; this is currently allocated 90 credits or half of the credits for their degree. The one module which is compulsory to all, yet currently not part of any credited programme, is Study, Professional & Analytical Skills (SPA). Tasked with making SPA 'credit bearing' as part of a Departmental Academic Review of 16 postgraduate programmes, the SPA teaching team are in the process of improving the academic quality of the module content whilst enhancing individual student support. As part of the changes, the credit value of the Dissertation will change from 90 to 60 credits.

This paper looks at one of the processes involved in planning the future SPA Module: a benchmarking exercise in which a comparative analysis of the three subject areas (Engineering Management: Supply Chain / Logistics Management: Project /

Operational Management) was undertaken across the UK Higher Education Sector. The paper concludes by identifying how the benchmarking exercise is being used to inform the development of the new module and by commenting on the response to the current 'Covid19' Pandemic while situation, questioning to what degree the current situation will impact future provision.

2. Why Prepare Students for their Dissertation? A question of 'transferable skills'.

Throughout the first two decades of the 21st Century numerous academic studies have focused on *what* skills and competencies future engineers need to learn in terms of technical content[1,2] whilst other have highlighted the need for engineering students to be equipped with 'softer' transferable skills including academic writing, verbal presentation and critical thinking skills[3,4,5]. However, in 2020, as the Covid19 Pandemic spreads across the world, the need to expand the public mind-set about what engineering is and what engineers *do* has possibly never been more important[6,7]. Indeed, the global expectation that engineering companies respond to the current crisis by providing fast, viable solutions to a global demand for medical equipment, such as ventilators and protective clothing, is unprecedented[8]. Likewise, the need for highly skilled logisticians, able to envision and enact the supply chain at a time when demand is unparalleled, has brought an academic discipline that usually sits on the edge of what is considered 'engineering education' to the public forefront[9].

It is within this contemporary global context that this very local paper is set. Drawing attention to the practical and pedagogic problems of equipping a cohort of over 1,200 students with the necessary skills to conduct an independent piece of research. This was challenging before Covid19, at this moment in time sometimes feels overwhelming. Grounded in a model of engineering education proposed by two of the paper authors[10] and set within a prestigious Russell Group University, the discussion in this paper highlights the challenges of designing and implementing suitable provision for a multinational cohort of students.

2.2 The Context: Employability & Pedagogical Frailty

In considering the role played by higher education in equipping graduates with transferable employability skills, one key factor determining what students within the European Union are taught is the Bologna Declaration [1999] and the EHEA[12]. Since Bologna, numerous EU treaties and agreements[13,14] have shaped how engineering and other university courses are designed with the concept of employability being shared across programmes, disciplines and countries alike. Likewise, a number of academic studies have considered what skills new graduates are expected to possess upon becoming employed[15,16]. Additionally, a considerable body of literature looks specifically at the employability skills and competencies that engineering graduates need to possess upon graduation[17,18,19].

In considering the task of preparing engineering and engineering-related students for success at postgraduate level, the teaching team adopted an approach developed by two of the paper authors, that of Synergetic Configuration within the auspices of the RVS Model of Engineering Education[10,20].To assure academic rigour and validity, the RVS Model was considered from the epistemological stance proposed within the concept of pedagogical frailty[21,22]. It is important to note that culturally, immediately prior to the project taking place, the faculty had undergone a period of organisational change, something which had unsettled some colleagues[23, 24]. For the module concerned such change was necessary as, up until this point in time, learning has been scaffolded onto a teacher-centred pedagogy whereby facts and theories were transmitted by rote and deep learning did not occur[25,26].

2.3 WMG: Reviewing & Renewing Study & Methodological Skills Training

WMG represents one of the largest postgraduate engineering education faculties within the UK. In 2019 / 2020 there were over 1,500 mostly full-time students enrolled on a range of engineering and engineering management related programmes. The Study, Professional & Analytical Skills (SPA) Module is taught to over 1,200 full-time, residential students, the majority of whom originate from China and surrounding countries. A critical review of the module occurred in the summer of 2019 and revealed four areas whereby the module content needed to be enhanced for rigour and validity:

1. Poor student engagement in study skills sessions

2. Sporadic engagement in research methods lectures

3. An overloading of information on the VLE

4. A lack of constructive alignment[27] with wider programmes and inadequately aligned learning outcomes.

3. Comparative Analysis of Cross-Institutional Provision: The Approach

The purpose of conducting a benchmarking study of study skills and research methods training at MSc level within the UK was to enable the teaching team to gain an understanding of how comparable programmes support and prepare students to conduct an independent piece of research.

3.1 Methodology

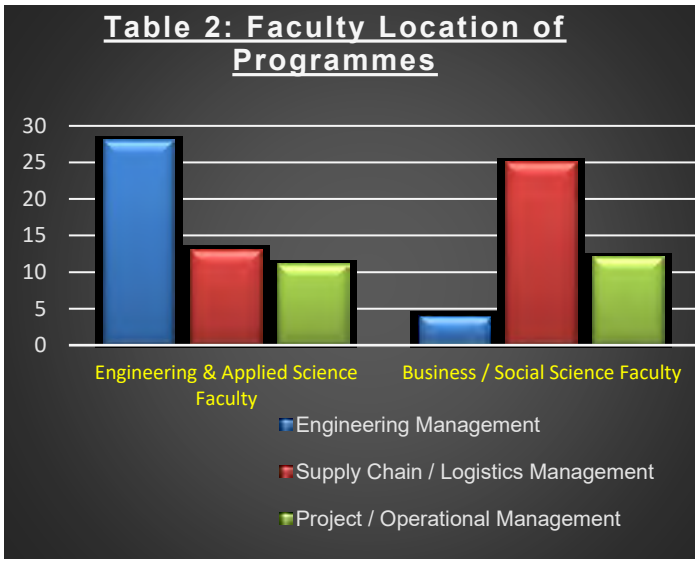
An analytical framework was developed and the following variables recorded: Name and type of HEI offering one of the three courses (all data has been anonymised prior to publication),: Provision of pre-dissertation study skills and methodology training: Number of credits allocated to pre-dissertation study skills and methodology training: Faculty in which the courses were offered (Engineering / Applied Science, or Business / Social Science). Within the sample of 62 HEIs, 90 separate courses were identified in total. Of these, 70 offered research methods and study skills training to students as part of the formal learning programme.

4. Cross-Institutional Provision of Support for MSc Project: Findings

The first variable examined related to the amount of credits associated with the MSc Dissertation. Looking at the three subjects separately, the data in Table 1, below, reveals that the vast majority of projects were given a credit value of 60 *[N =54]*. The lowest number of credits allocated to the dissertation was 30. One institution offering an MSc in the subject of Supply Chain / Logistics Management did not have a Dissertation.

Table 1: Credit value allocated to MSc Dissertation by Subject area.

Credit Value for Dissertation	Engineering Management	Supply Chain / Logistics Management	Project / Operations Management	*n*
60	20	20	14	54
45	2	3	2	7
40	1			1
30	1	1		2
Not shown	8	13	7	28
No Project		1		1
Total	32	38	23	93



Having looked at the credit value of the programmes, the next task was to identify in which faculty the three programmes were offered. Table 2, below reveals that the vast majority of Engineering Management courses are offered in Engineering Faculties. Conversely, the opposite is true of Supply Chain / Logistics courses where most are provided in a Business School setting. Project / Operational Management course were almost equally spread between the two.

The data shown below in Table 3 shows that the provision of research methods per faculty. It reveals that 74% of courses in Engineering Faculties and 78% in Business or Social Science faculties provided a credited study skills and / or research methods training for students. Table 4, below, shows the majority of the study skills and / or research methods modules had a value of 15 credits (7.5 CATS).

Table 3: Total courses offered by faculty & provision of credited study skills and research methods training

Faculty	*N [% of total]*	*Accredited Study Skills / Research Methods training: N [% of courses offered]*
Engineering / Applied Science	53 [57%]	39 [74%]
Business / Social Science	40 [43%]	31 [78%]
Total	93	70

Table 4: Credit value of study skills / research methods training across the sample

Credit Value	*N*
30	2
20	15
15	25
12	2
10	3
Credit rating not noted	25
No module offered	21
Total	**93**

5. Discussion: Building a 'Credit Bearing' Module to Support the Dissertation and Wider Studies

Having established the uniqueness of all three subject areas within a Faculty of Engineering (only one other Engineering Faculty offered all three courses), the work required to make SPA a '15 credit' module began. With the first Intended Learning Outcome focusing on Independent Learning Skills, the need to develop a signature pedagogy which serves the needs of 16 different courses and a largely international cohort is of paramount importance[28,29]. As such a diverse range of subjects are offered with the first few weeks, covering a range of topics including: 'An introduction to Academic Writing'; 'Using the Library'; 'Note Taking'; Avoiding Plagiarism'; 'Critical Thinking'; 'Joining a Professional Body'; and 'Studying in the UK'. Following the student learning journey, 'Ethics in Research and Applying for Ethical Approval' is introduced at the beginning of term 2, whilst high level 'Analytical and Study Skills' sessions are delivered throughout terms 2 and 3. Learning provision continues beyond term 3 into the summer whereupon attention turns to 'Writing at a Graduate Level' and 'Constructing a Dissertation'.

As the necessary planning and quality control process for the credit bearing module were just about to be enacted, the Covid19 Pandemic hit the UK, resulting in face-to-face teaching being replaced by a 100% on-line approach. This put additional pressures on the team as the need to prioritise current offerings over future options took precedence. However, on the plus side, the enforced period of intense working has enabled a pedagogically and strategically module to be developed. One that is academically aligned to the wider programmes and modules and in which a more academic emphasis on Professional Skills is being introduced alongside Study and Analytical Skills. From October-December 2020 SPA: Study, Professional & Analytical Skills, will support students throughout their postgraduate learning journey by offering a combination of synchronous and asynchronous learning experiences. This has been achieved by:

i. Developing and designing the curriculum based upon the concept of **Synergetic Configuration** introduced within the **RVS Model of Engineering Education** developed by Clark & Andrews (2014)[10].

ii. **Purposefully developing and designing learning materials** to fit into one of the three main strands:

- **Study Skills:** Study skills is divided into three distinctive phases. The first one, aimed at engendering a sense of belonging within individual students[29.30,31], is aligned with 'Welcome Week' and included a formative piece of written work. A 'marking and feedback' rubric is being developed to enable to teaching team to mark and provide feedback within the first few weeks of term.
- **Professional Skills:** This new stream has been purposefully designed so as to make sure that the module is academically **<u>and</u>** vocationally

relevant. Bearing in mind the need to create a module which will form part of a number of programmes that are accredited by different professional bodies, employability and the need to equip and measure students' transferable skills is central.

- **Analytical Skills:** The final stream relates both to critical analytical skills and research methodology. A significant change to the previous provision is the introduction of workshops on how to use 'online' analytical and other research tools. Whilst the majority of this stream focuses on management research, aimed at equipping future engineering managers with the ability to conduct a piece of industrially valid management research, topics such as advanced statistics, experimental approaches and other technological / engineering research methodologies are offered alongside 'expert workshops'.

iii. **Redevelopment of Learning Materials:** The learning materials are being re-written so as to better reflect the wider requirements of all of the MSc programmes. All learning materials will be provided in a range of different formats including: Small group workshops: Large group teaching sessions held at weekends: Specialist tutorials: Pre-recordings of key content: Workbooks: On-line provision including interactive quizzes and short films.

iv. **Redesign of the VLE:** The VLE is constantly being refreshed and renewed and will again be completely redesigned for the beginning of the new academic year.

v. **Improved Student Communication & Support:** Weekly updates and emails are sent to the students to remind them of what is occurring in the following week and also to send useful hints and tips about learning. Additional 'wellbeing' support and academic tutorials are offered.

6. Concluding Remarks: Moving forward at a time of uncertainty

This paper relates to an ongoing project in which the teaching of Study, Professional and Analytical Skills is being reviewed and renewed with the intention of making sure that students are academically supported in such a way that provides them with the necessary high-level skills needed to succeed. Developing, designing and introducing a credit bearing module to meet the needs of an academically and ethnically diverse group of students, studying on 16 different courses has proved challenging. The fact that up until this point in time the module was not incorporated as an academic component of the wider programmes which meant there was a lack of ownership and leadership. Conversely, when redesigning the module, problems arose in which colleagues insisted their course requirements be prioritised over others. The SPA module has a full-time teaching staff of 2 with a module lead allocated 0.2 of their role dedicated to managing the module. Given the number of students, which is expected to be similar in the academic year beginning in 2020 despite Covid19, the staff-student ratio is exceptionally low. This has proved a challenge throughout the module design process.

The Covid19 Pandemic has seen the whole of the current module content move on-line in a matter of days. Having pre-recorded key content, the teaching team were at an advantage in comparison to other colleagues. Hence in the period when formal teaching was temporarily suspended to allow materials to be streamed via Microsoft Teams, full use was made of the Study Skills and Research Methodology tools and materials. Furthermore, for a short period of time the SPA team were the main academic team supporting students as lectures were suspended due to lockdown with students returning to their home countries. Providing a high level of academic support over this period of uncertainty enabled students to continue to work on their dissertations whilst awaiting the recommencement of teaching.

In conclusion, the benchmarking exercise discussed in this paper revealed that WMG is the only UK university currently offering a 90 credit Dissertation for the three subjects examined. It is also one of only a handful of HEIs that does not currently offer a credit bearing *study skills and research methods* focused module. That both of these are being changed in the future can only be good news for the student experience and whilst Covid19 has slightly changed the 'goal-posts', the teaching team remain dedicated to developing a highly transferable and excellent quality resource.

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LEARNING RESOURCES FOR SUSTAINABLE DESIGN IN ENGINEERING EDUCATION

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ABSTRACT

This paper presents the results of the Circular Design Project, European project funded by Erasmus+ Knowledge Alliance within the social business and the educational innovation field. The project have three major learning objectives: to increase and improve the learning strategies of Design for Sustainability; To gather and cluster open educational resources in Innovative Design for Sustainability; To train up innovative and entrepreneurial designers in Design for Sustainability.
This was achieved through a knowledge co-creation process and the development and pilot training materials in order to teach and train students, faculty and enterprise staff of the design sector.
The project formed by 12 partners is organised around four country hubs in Ireland, The Netherlands, Catalonia and Sweden. Each country Hub consists of one university, one company and one national design association. The project main results are:

- The Open Educational Resources database (http://circulardesigneurope.eu/oer/) where resources in Circular design are clustered in three taxonomies: Categories (First-timers; Practitioners), Level (Beginner; Intermediate; Advanced) and Tags (calculator; report; …).
- The Best Practice Publication, shows the whole design process, materials, challenges, problems and other key issues of Circular Design case studies
- Four international one-semester internships for undergraduate design students in the four universities with the participation of 11 companies and 45 students.
- The Circular Design Digital Fabrication Lab Handbook to introduce students, companies and academics to the open-source, participatory, experimental and design & build approach within digital fabrication labs.
- The Professional Development Course in circular design.
- The Policy Paper in Circular Design Education

1 INTRODUCTION

The Circular Design - Learning for Innovative Design for Sustainability (L4IDS) project (http://circulardesigneurope.eu/) is a three year (2016-2019) Erasmus + Knowledge Alliance financed project.
The consortium consisted of 12 partners (4 Universities with education and research in Design and Sustainable Design, 4 Design Companies with expertise or interest in Sustainable Design and 4 Design association of the country) organised around country hubs (Table 1).

Table 1: Circular Design Partnership.

Country hub	Catalonia	Ireland	Sweden	The Netherlands
University	Universitat Politècnica de Catalunya	University of Limerick	Linköping Unviersity	NHL University of Applied Sciences
Company	NutCreatives	One-Off	Habermann	Ceci N'est Pas Une Holding B.V
Design professional body	Barcelona Centre de Disseny	Institute Designers Ireland	Swedish Industrial Design Fundation	House of Design

The goal of the project is to promote sustainable consumption and production of products and services in Europe. This is achieved through a knowledge co-creation process and the development of training materials, through Open Educational Resources (OER), in order to teach and train students, faculty and enterprise staff of the design sector in Innovative Design for Sustainability (IDfS) strategies (Figure 1).
The project is alig
ned with European Circular Economy policies and contributes to the realization of a more sustainable society.
The evolution of the DfS field has broadened its theoretical and practical scope over the years [1]. While the first approaches of the early 90's, were focusing predominantly on the technical approaches of sustainability [2], the following ones have recognized the crucial importance of the role of users, resilience of communities, and more generally of the various actors and dynamics of socio-technical systems [3, 4]. This evolution has been accompanied by an increased need for human-centred design knowledge and know-how. Initial DfS approaches related to the product innovation level predominantly requiring technical knowledge and knowhow. On the other hand, more recent DfS approaches require designers to be provided with a different set of expertise. For example techniques to gather insights from users, news ways of satisfying customers and techniques to co-design with them are essential [2]. The project presented here aims at influencing the overall system, from the physical product to the socio-technical level.

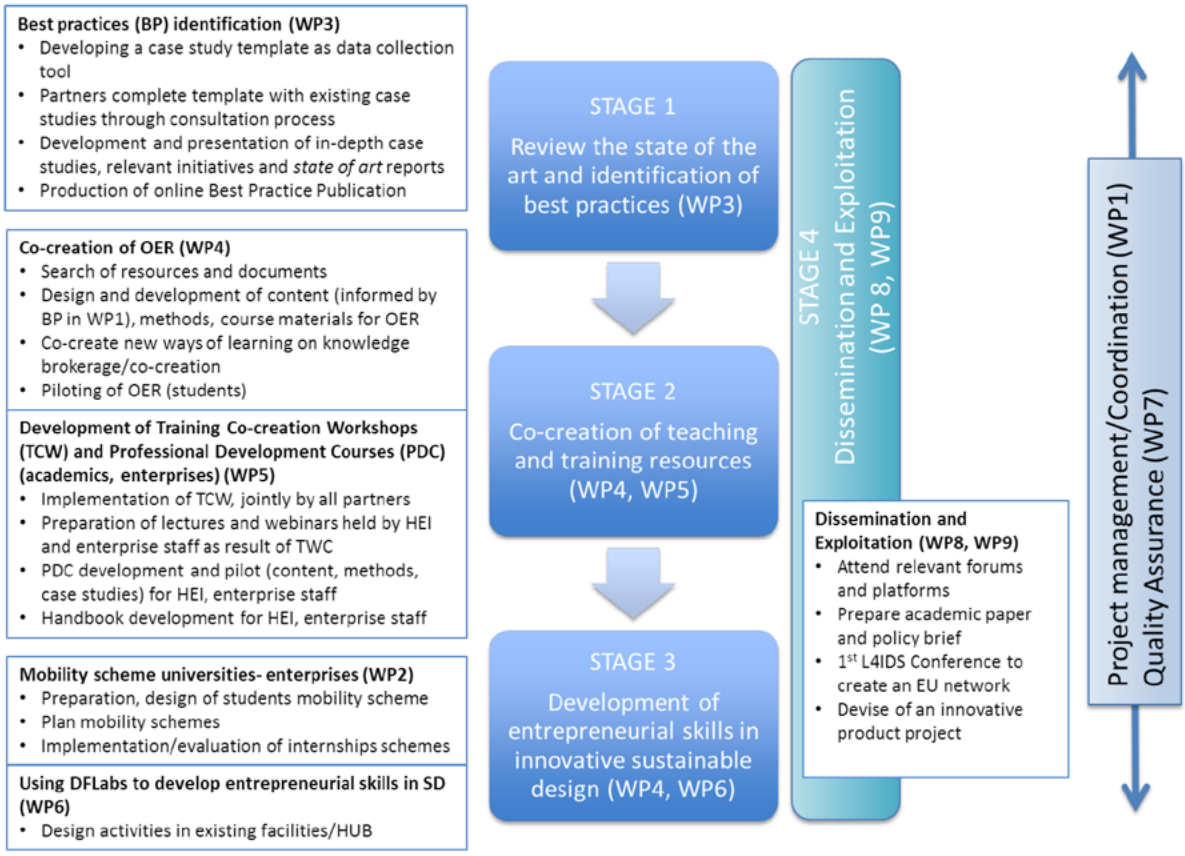

Fig 1: Circular Design – Learning for Innovative Design project rationale.

The overall objective of the project is to promote sustainable consumption and production of products and services in Europe. To achieve this main goal during the project the partnership co-create open-source training materials, and organised four international internships for design students in order to teach and train students, faculty and enterprise staff of the design sector in Innovative Design for Sustainability (IDfS) strategies

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The project co-created training materials are:

- Best Practice Publication
- Open Educational Resources Database
- International Internships for students scheme
- Professional Development Course and handbook for capacity building and
- Policy Brief in Circular Design Education
- Digital Fabrication Lab handbook for Circular Design.

2 METHODOLOGY

The methodology applied is participatory action research. We carried out 3 co-creation workshops with the participation of 29 companies, 45 design students and 40 design academics, where the different outcomes were discussed and agreed.

Moreover the different training resources has been piloted and assessed in the sequential four internships during the three years of the project.

3 RESULTS

The Project is structured around the tangible expected outcomes structured in work packages. Next sub-sections show the results achieved. All results can be downloaded from the project website: http://circulardesigneurope.eu/

3.1 Best Practice Publication

NutCreatives partner was in charge of coordinating the ideation, prototyping and publication of best case studies publication (Figure 3). Relevant case studies, based on real company successful experiences have been released and disseminated along the duration of the project, and eventually collected in an e-book. Emerging and consolidated companies of diverse fields have been collaborating drafting the case studies. Aside from specific results and the great quality of the final product, the insights resulting from these collaborations processes among the different companies involved were of invaluable contribution for the project experience and for the companies themselves.
The eleven case studies represent the diversity of sustainable designed products and services in Europe. They are from really different sectors like technology, urban furniture, waste management, clothing and accessories, food packaging or furniture to show how sustainable design strategies can be applied in every sector. The result is a collation of well implemented business models based in excellent products, showing the creative process and the strategies that made them innovative and profitable.
We put a lot of energy into the creation of infographics that allow different levels of reading, to illustrate the different process and methodologies in a clear way. This includes concept maps, icons, tags, etc. but also longer texts that show the information achieved during the interviews. The Publication contains 11 case studies (Figure 2).

3.2 International Students Internship Program

The universities involved in the project developed an International Internship program for Circular Design with an adoptable schedule conforming to the structures of these universities. The aim of the program is to promote a culturally-diverse, interdisciplinary working environment for students from varying backgrounds (i.e. Product Design, Business, Materials Science).

Fig. 2.Best Practice Publication (http://circulardesigneurope.eu/best-practices)

Fig. 3.Circulr Design DFLab Publication (http://circulardesigneurope.eu/dflab-handbook)

To develop the internship the action research approach was used as developing an adaptable Circular Design internship program, where different institutions from different cultural backgrounds and pedagogical perspectives are involved and the development of the program, requires reflection of the involved researchers on the existing design education. Hence, in line with the action research cycle steps of reflection, planning and action [5], the collaborative action research framework in Figure 4 was developed.

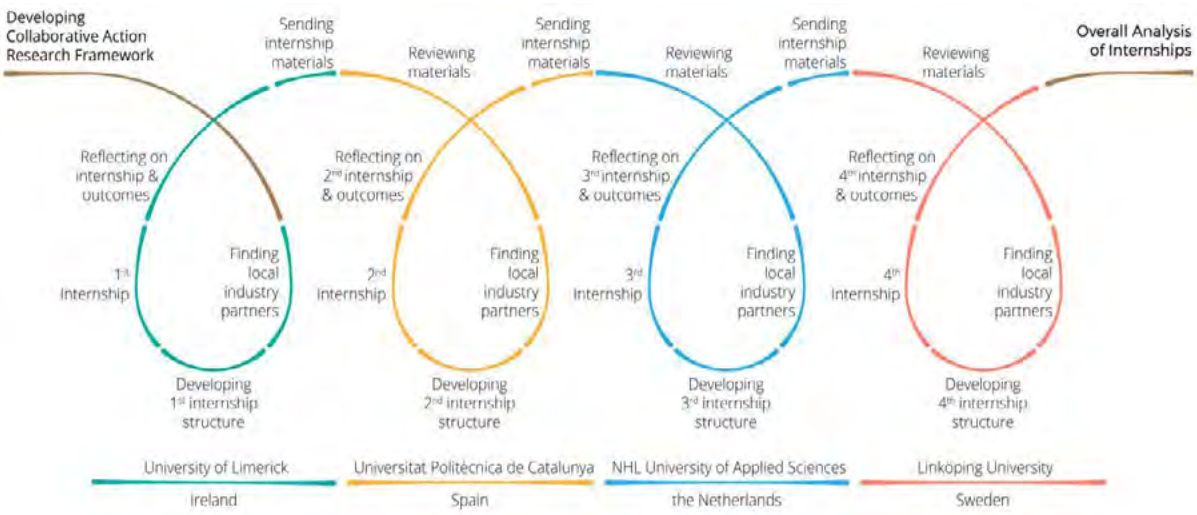

Fig 4: Collaborative Action Research Framework developed indicating the internship cycles. (Adapted from Bakirlioglu et al., 2018)

3.3 Circular Design Open Educational Resources Database

A database collating tools and methods for Design for Sustainability and Circular Economy, presenting them in different and easy-to-navigate categories was made available through the project website, and widely disseminated to different stakeholders. The database was designed to be consulted according to different levels of expertise, from first-timers to experts. Furthermore, the technical design of the database allows researchers, educators and practitioners to easily upload and share with the design community their OERs through the portal.

3.4 DFLab handbook for Circular Design

The handbook (Figure 3) is an introductory guide to bring together digital fabrication labs (e.g. FabLabs, hackerspaces, makerspaces, etc.) and the related practices enabled through digital knowledge sharing into design education for sustainability and Circular Economy. It introduces terms of these newly espousing fabrication spaces and the communities around them, potentials of these spaces for sustainability and Circular Economy. The contents of this handbook were used as a base for delivering masterclasses as part Circular Design Internships conducted during the project.

3.5 Professional Development Course and Handbook for Circular Design

Based on the experience and knowledge gained through project outcomes - and specific co-creation workshops held jointly with university and enterprises in the different partners' countries - an online handbook (Figure 5) aimed at guiding knowledge co-creation processes among staff of university and enterprise in IDfS have been published. This training resource aims at providing universities and design enterprises a selection of useful resources, strategies, training methods and step-by-step recommendations in order to engage with IDfS in professional practices and to foster entrepreneurial skills in this specific field. The content of this handbook has been drafted as a working base to develop/structure professional development courses on IDfS

3.6 Policy Brief in Circular Design Education

A policy brief (Figure 6) based on the project's outcomes has been drafted and disseminated. This outcome constitutes a call for action aimed at integrating Circular Design in policies of the European Union particularly addressed to Circular Economy. Specifically, it states that circular design thinking and development should be implemented throughout all of European policies and sectors: i) starting with education in schools and universities; ii) offering a lifelong learning covering all sectors, including policy makers and iii) continuously adding high level sustainable development for all professionals and business types.

Fig. 5. Circular Design Handbook Publication (http://circulardesigneurope.eu/handbook-in-innovative-design-for-sustainability)

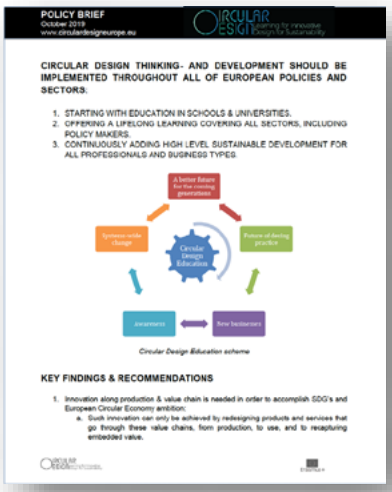

Fig. 6.Circulr Design Education Policy Brief (http://circulardesigneurope.eu/policy-recommendations)

4 ACKNOWLEDGMENTS

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SUSTAINING PROFESSIONAL LEARNING COMMUNITIES

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ABSTRACT

The Dutch horticulture sector has to deal with challenges related to sustainability and advancing technology. Engaging professionals and (engineering) students by working together in learning communities (LCs) is an emerging approach to respond to 'wicked problems'. In the Greenport West-Holland there are different types of these public-private collaboration initiatives. They work and learn together in LCs in order to innovate. Research has been done on how to start a LC, however it is not completely understood how it can (effectively) last. This research, funded by the province of South Holland, aims to gain insight into what it takes to engage participants of LCs in the longer term. Our research question is: What factors contribute to sustainable learning communities in the Greenport West-Holland? We interviewed public and private partners (n=10) of five LCs. All interviews were recorded, transcribed and analysed in Atlas Ti. Results show that collaboration between private and public parties is crucial in a sector in transition. Different disciplines come together: technical domains (e.g. robotization), horticultural knowledge, business and educational knowledge. The type of LC matters. The analysis revealed that to sustain the collaboration the LC should focus, among other things, on attracting people with drive and personal commitment to the shared ambition (instead of inviting organisations), should continually work on community building and show intermediate outcomes of actions and impacts. Identified

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preconditions for sustainable LCs are a good reputation and and long-term (financial) support.

1 INTRODUCTION

1.1 The challenge

The strategy of Greenport West-Holland, world-famous for its greenhouses, flowers, fruit and vegetables, is explained on the website: 'Greenport West-Holland started the "Feeding and greening the megacities" strategy. The core of this strategy is that the region […] provides megacities in Europe with food and happiness and develops concepts for mega cities elsewhere in the world.' [1] To move towards this ambitious strategy, the Greenport West-Holland horticultural cluster has identified several innovation tasks, such as developing into the first climate-neutral Greenport in the Netherlands. To achieve this, the Greenport sees public-private partnerships (PPPs) as an important approach and has set up several collaborations for conferences, masterclasses, courses and co-creative and co-innovation projects. 'All the activities aim to stimulate collaboration between universities, vocational schools and companies preferably on a global scale and stimulates cross-overs and the connection between students and business and support them to innovate' [1]
Over the past decade, many forms of public-private collaboration have emerged in the Greenport. As Harm Maters, the (former) deputy chairman of the Hortivation Foundation said: 'The affiliated companies realise that structural and joint innovation [with knowledge institutes] is vital in order to stay ahead of the competition. […] After all, you are able to take bigger steps when working collectively, especially when it concerns problems or developments that affect multiple companies at an international level. An example that comes to mind is that of making greenhouses earthquake-proof.' [2]
Although there are many innovation initiatives in the Greenport, they are often not fully implemented for a variety of reasons. It is difficult to work in a consortium with diversified interests. [3] [4] Furthermore, all parties involved are enthusiastic in the beginning; their contribution, however, bears the risk of diminishing with time. We should know more about what can be done to effectively sustain a learning community (LC) to achieve and scale up innovations. Moreover, engineering students and teachers, among other stakeholders, should learn how to participate effectively in these types of collaborations. The study aims to understand the factors that play a role in sustaining professional LCs in the Greenport.

1.2 Definitions

The LCs in the Greenport we are investigating are PPPs. They are framed differently by its stakeholders: field labs, (learning) communities, living labs, etc. We should take into account that they come in various shapes and sizes, with different goals and 'stages in life cycle'. [5]

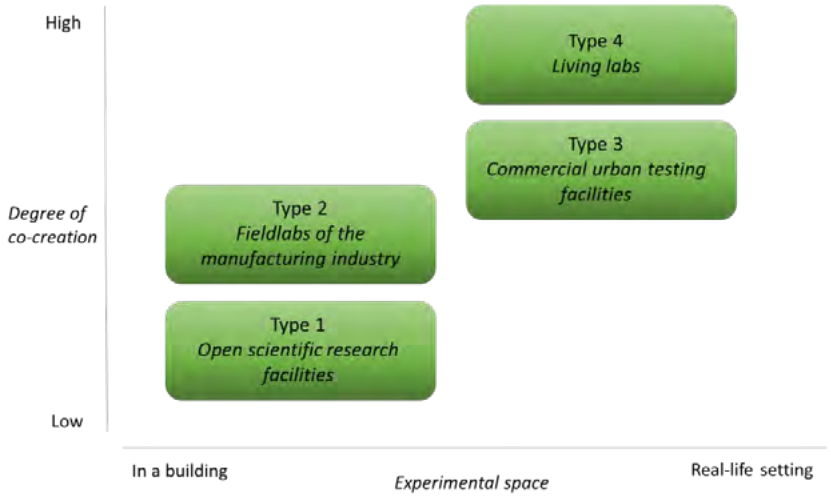

Fig. 1. Four basic types of collaborative initiatives [6].

In the Rathenau report, four basic types of collaborative initiatives are distinguished, based on two dimensions. These public-private initiatives differ from each other on the level of co-creation and the diversity of partner types (scientists, entrepreneurs, students, citizens). The second distinction is whether the experiments are carried out in a physical space such as a laboratory on a university campus, or in a real-life setting, such as a city's neighbourhood. An example of a field lab (type 2) in the Netherlands is 'Aqua Dock', a test facility for floating structures in the harbour of Rotterdam. An example of a living lab (type 4) is 'Circulair Buiksloterham', facilitating the development of a previously industrial region in Amsterdam Noord, into a sustainable and circular district. [6]

In literature, a field lab is often described as a partnership between companies and public organisations. [7] Field labs (type 1-2 in Fig. 1), compared with other PPPs, primarily focus on research and innovation. Research and development activities are carried out in such a way that the new knowledge and equipment (eventually) can be used by the industry to remain 'state-of-the-art'. The overarching goal is to strengthen the competitiveness of the industry by learning together for instance about the application of new technologies. Type 1 and 2 partnerships give companies better access to knowledge and research facilities of public knowledge institutions such as universities. In type 3 and 4, co-creation with a wider variety of parties is important (for instance citizens' initiatives), as well as in 'a real-life setting'. [6] We use the terms field lab, LC and living lab interchangeably and define the common denominators as follows: 'A partnership between private and public parties where learning, working and innovation are interconnected, with sufficient attention to the innovation challenge. The cooperation between the different parties is the added value of the field lab/LC. The cooperation is (partly) made possible by public financing. The LC performs (learning) activities and has a collective intention to deepen a knowledge domain and improve practices.'

This paper will focus on sustaining professional LCs. 'Sustaining' or 'sustainable renewal' is also not a straightforward concept. Following März et al. we define 'sustainable renewal' as a process rather than a final stage. [8] In this paper, it is

about the extent to which the LC can be further developed. Therefore, sustainable innovative change requires a continuous process of generating innovative, collaborative knowledge that can improve practices.

2 METHODOLOGY

Our research question is: *What factors contribute to sustainable learning communities in the Greenport West-Holland?*
Five LCs were selected based on the following criteria. The LC is a PPP, receiving public financing, and one of its objectives is innovation in the Greenport. The PPP has been in place for some time (e.g. not in the initial phase). We started with a list of existing LCs in the Greenport, provided by the Province South-Holland, and the innovation pact. We mapped these LCs against the selection criteria. We were aiming at a maximum variation of types of LCs. Therefore, after selecting two field labs (type 1-2), we decided to search for PPPs that could offer an additional perspective, using a snowball procedure through the networks of the authors and experts in the Greenport sector. We contacted the private or public partner of the LC and asked him/her to connect us with one of the other partners. As a result, following the distinction made by the Rathenau Institute [6], the collaborative initiatives in our sample are two type 1-2 LCs and three type 3-4 LCs.
For each LC, we interviewed a public actor, typically a university-affiliated researcher or a representative of the province, and a private actor, such as an entrepreneur or an innovation manager. In total, we held 10 in-depth interviews. The interviews were conducted from December 2019 until June 2020 and lasted 80 minutes on average (ranging from 65 to 106). The authors conducted the interviews in pairs, using a semi-structured interview scheme. Each interview started with general questions about their profession and company or organisation. The second block contained questions concerning the goal and activities of the LC and the role of the interviewee in the collaboration. This was followed by blocks of questions about the barriers and facilitators they encounter in the LC over time, examples of the revenues they generated and what it takes to use innovative ideas to transform practices. Finally, there were questions relating to what instrument(s) they need to take the LC a step further. In addition, to get a wider perspective of the sector as a whole, we interviewed several experts in the Greenport sector. The interviews were recorded and transcribed. All the transcripts were analysed with qualitative data analysis software.
To analyse the data, we used open and axial coding. One author created codes, grounded in the interviews, in several rounds. The three authors, together with two fellow researchers, subsequently started the process of axial coding. They compared, discussed and grouped codes. Those codes were assembled into factors. Finally, the factors were put together in clusters.

3 RESULTS

Based on the rich data from the interviews, in this paper we will discuss the factors that were mentioned most often and that were identified by most LCs. These factors

are clustered as follows: 1) person-related factors, e.g. the roles and characteristics of the participants 2) process-related factors, e.g. the working method in the community 3) content-related factors, concerning the content of the innovation that is central to the LC, and 4) preconditions, describing factors that are considered a necessity to subsequently achieve a result. The combination of factors that contribute to sustaining LCs in the Greenport West-Holland are listed in Table 1.

Table 1. Factors for sustainable LCs

	Clusters	*Factors*
1.	***Person-related***	*1.1. Drive, personal commitment*
		1.2. (The sum of) competences, roles
2.	***Process-related***	*2.1. Community building (continually)*
		2.2. Competitive sensitivity
		2.3. Awareness of the value of interdependence
3.	***Content-related***	*3.1. A shared vision of the future: 'pole star'*
		3.2. Intermediate outcomes of actions and impacts
4.	***Preconditions***	*4.1. A good reputation*
		4.2. Long-term investment, (financial) support

The analysis of the five LCs also shows that the type of partnership makes a difference. However, the contrasts and similarities between types 1-2 and 3-4 LCs need further consideration and are beyond the scope of this paper. That also applies to factors relating to the ecosystem within which LCs develop.

3.1 Person-related factors

Drive and personal commitment

To sustain a collaboration in a LC, 'having drive' and 'being personally committed' seem to be essential for everyone involved. According to the respondents, 'being driven' is about perseverance, passion, believing that this is the right way to go and that you are the one who can make a change: 'People who really want the energy saving to succeed' (university affiliated researcher). Personal commitment is the basis for sustaining participation in LCs. Therefore, it is important to keep addressing 'participants to their values because then they can [still] relate to the story'. When looking for new members, select the person rather than the company or organisation they represent as such.

(The sum of) competences, roles

Ensuring prolonged participation in LCs, however, requires more than 'just' having drive. A variety of personal characteristics of the participants have been mentioned. Because it was often the sum of these qualifications that were considered to be essential in sustaining LCs, specific roles could be distinguished. For instance, the role of the community manager: 'That is what keeps such a community together. [A person with] both knowledge, passion and vision, is the core of the community.' (project manager). A community manager must have substantive knowledge [of

horticulture], be able to 'level' with different parties, maintain a network and generate enthusiasm in a group (social skills). Other (preliminary) roles we envision are (programme) mediator (all types), project manager (type 1-2), innovation manager (type 1-2), pioneer (type 3-4), connector (type 3-4), and ambassador (type 3-4). The essence here is that you need to combine competences and roles: it is not 'or/or' but 'and/and'.

3.2 Process-related factors

Community building (continually)
Working together in the longer term also depends on the extent to which the LC succeeds in building a community where participants 'feel seen and heard' and in which members of the community trust each other, can seek connections, ask questions, and start (new) collaborations. It seems obvious but things don't happen by themselves. In addition, maintaining relationships and generating trust takes time and companies, in particular, often have an accelerated time frame compared to public partners. This makes the collaboration more complex.

Competitive sensitivity
Competition in the sense of maximising individual profit and to gain something by establishing superiority over others (win-lose situation) is a constraint that LCs have to deal with.
The type of company or organisation that participates, the way they perceive their 'competitor colleagues', as well as the innovation phase, play a role. In general, it is easier to collaborate in the pre-competitive phase. Sometimes, however, it is precisely the process of sustaining the collaboration that proves to be difficult. In addition to companies, competitive sensitivity also plays a role for public parties, for example knowledge institutions: 'And of course it gets a bit busy with all the knowledge input' (university affiliated researcher).
LCs should be aware of this competitive sensitivity and should deal with it in various ways. For instance, by inviting specific contributors and encouraging horticulturists to work in smaller groups so that mutual trust has a chance to grow. This can be achieved by dividing up areas of attention so that everyone contributes to a different part. The design of the meetings can also make a huge difference in this respect.

Awareness of the value of interdependence
'There is no place for egos', stated one of the participants. Participants must be willing to collaborate in the longer term. This is strongly linked to striving to achieve a shared ambition, for which participants have to be willing to step beyond their own interests and work towards the common goal. In their working method, the LC should create participants' awareness of their interdependence in achieving this ambition. Also, to mature the collaboration, part of the working method entails dealing with other 'cultures' and being aware of the differences in the decisiveness and tempos of different participants. Otherwise, 'People will be working in a multi-tiered system' (private partner) and have dissimilar expectations.

3.3 Content-related factors

A shared vision for the future: 'pole star'

A shared vision is a basic condition that must be worked on continuously. That vision acts like the brightest star in the sky: the pole star. At the same time, it is important that the individual roles in the shared ambition are made explicit: 'What do we want to do next? What promising plans and ideas are there for the individual group members? Well, we bring these people and ideas together' (representative of the province).

Intermediate outcomes of actions and impacts

The added value of their involvement in the LC is important for every participant. For example, a private party indicated that participation provides knowledge and contacts with other companies: 'So these are all valuable things. But the bottom line is, you want to know what we gained [in money]?' (private partner). Type 1-2 LCs provide small-scale proof-of-concept i.e. the harvesting robot. However, it is necessary to prove the impact on a larger scale and/or the commercial potential, especially if the innovation is risky and complex. However, here you often see a vacuum between development and application. For type 3-4 LCs, the added value is in implementing experiments, such as increasing biodiversity by sowing flowers. Celebrating these types of successes also helps keep the energy high (mentioned in all types of LCs).

3.4 Preconditions

A good reputation

In order to sustain the collaboration in the LC, it is important that the community keeps growing and attracting the 'right' people. When the LC has a good reputation and a well-known organisation or an important entrepreneur in the sector is already involved in the community, this helps attract new partners. The LC can build a positive image by sharing successes with external stakeholders. An ambassador can help with this, they include people in the story of the LC by 'Telling, telling, telling' (private partner) and turn something abstract into something very practical.

Long-term investment, (financial) support

For all types of LCs, it was emphasised that financial (public) support is essential, not only at the start of the community but on a structural basis. In addition, various other forms of support can be distinguished that promote further development of the collaboration, e.g. by making equipment or expertise available. You can also look beyond your own sector for this.

4 CONCLUSION

In this paper, we investigated the factors that contribute to sustainable LCs in the Greenport West-Holland. Our research revealed that relevant factors to sustain a LC can be grouped into four clusters: 1) person-related, 2) process-related, 3) content-related, and 4) preconditions. In total, we considered nine factors in these clusters, which can be used as guiding principles for the further development of LCs.

Following on from our study, LCs should pay attention to attracting people with drive and personal commitment to the shared ambition instead of trying to attract organisations. In addition, it seems obvious that efforts should be made to build close long-term relations between partners involved in the LC, but that does not happen automatically and it takes a lot of time and effort to maintain those relations. The LC also plays an important role in handling competitive sensitivity between the partners. Moreover, LCs should show and 'celebrate' intermediate outcomes of actions and impacts, work on the reputation of the LC to attract new committed partners and guarantee long-term (financial) support. We have been able to distinguish different competences and roles that are all needed; it is 'and/and' and not 'or/or'. This also applies to the nine factors: the sum of these factors contributes to sustaining LCs. This is why sustaining LCs requires continuous care of all participants.

The results from this study add to the growing literature about LCs. However, most of the papers are about establishing and supporting LCs rather than keeping a LC effective in the longer term. In order for LCs to make use of the factors described in this paper, we are designing a tool that can be used by participants of LCs, as well in educational programmes within Europe.

Furthermore, our interview data also revealed factors for how to make more use of the revenues of the LC (forthcoming, not in this paper). These factors seem to be intertwined with the factors described in this paper. Impact must be made to enduringly involve partners in LCs and at the same time it is difficult to make that impact together. Moreover, further research should be done on the role of the context of sustaining LCs and the different types of LCs.

Many innovation challenges in the Greenport are technology related. Building environmentally-friendly greenhouses is a high-tech innovation, as is for instance 'precision farming'. Robot experts, data scientists and energy transition specialists are important. However, the (middle) management roles are also considered high-impact functions in the Greenport (forthcoming). Indeed, many technical inventions must be implemented (on a larger scale) to be profitable. Engineering students should be prepared for this transition. Therefore, students and teachers should know which relevant factors contribute to sustainable LCs and how to address these in the curricula. Which personal traits are relevant to contributing to different types of LCs and which roles can be distinguished? Furthermore, they should reflect on how to behave effectively in the community-building process and they should learn how to take advantage of being part of an open network. Moreover, engineering students will become the leaders of tomorrow. They will initiate, join or facilitate public-private collaborations and/or guide their employees to do this effectively. Fit for the future means engaging students in real-life challenges and collaborating transparently with a range of different stakeholders!

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QUIT YOUR SLOUCHING! - USING WEARABLE SENSORS TO INVESTIGATE ENGINEERING LABORATORY WORK ERGONOMICS

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Conference Key Areas: *Interdisciplinary education, Niche & Novel*
Keywords: *Laboraory, ergonomics, wearable sensors, posture, Upright Go*

ABSTRACT

Laboratory engineering students have a lot of laboratory work in their curriculum. After graduation, they typically work in various laboratories as specialists conducting research and managerial tasks. Laboratory work sometimes means awkward working postures and prolonged times of holding hands in the air. To prevent work-related diseases and to lengthen work careers in the long run, good posture and good workplace ergonomics are important aspects.

In this study wearable posture sensors are used to investigate the ergonomics in two teaching laboratories: biochemistry and instrumental analysis laboratory. Volunteer students were asked to wear posture sensors (Upright Go) on their upper backs during the laboratory work for two weeks. The data consists of temporal distribution of the times of having a good posture and a slouching posture, respectively. Physiotherapy students participated in the study by monitoring the engineering students' working in the laboratory, making ergonomics mapping and interviewing students and teachers.

Preliminary results show that according to the wearable sensor data, there is a lot of variance in postures between individuals and somewhat between laboratories. On average, students were sloughed 45 % of the working time in biochemistry and 34 % in instrumental analysis laboratory. Some of them were sloughed even 75 % of the time. The height of the students varied between 150 cm and 188 cm. Thus, the same fixed workplaces are not well suited for everyone, especially in the biochemistry laboratory.

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1 INTRODUCTION

1.1 Ergonomic problems

According to International Ergonomics Association (IEA), ergonomics is “the scientific discipline concerned with the understanding of interactions among humans and other elements. It is the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.” [1]. In Europe, the most common work-related problems caused by bad ergonomics are different musculoskeletal disorders (MSDs) [2]. In the United States, 45 % of Americans between the ages of 35 and 55 suffer acute back pain each year and it is the top cause of disability under the age of 45 in the US [3]. MSDs cause personal suffering and even early retirement, but they also cost businesses due to temporary assignments during sick leaves and due to reduced productivity. Nicholson et. al. [4] have conducted analysis of 29 cases in the UK and showed that the payback period of ergonomic interventions in those cases varied from just a couple of months to a few tens of months. Investments in reducing musculoskeletal risks had resulted in financial benefits to the companies through cost savings, increased productivity and quality of output. It should be noted, however, that cost-benefit analyses are difficult to conduct in the fields of health and safety and it is difficult to assign costs and benefits to ergonomics interventions.

Many factors affect the ergonomics at a certain work: Physical factors such as force application, repetition of movements, awkward and static postures; Organizational factors such as demanding work, low level of autonomy and monotonous work; Individual factors such as physical capacity and properties, age and prior medical history.

1.2 Laboratory work

In higher education institutions, the design of learning environments is based on pedagogical needs and principles. *Learning environment needs to be also authentic for the topic and field of engineering*. Thus in engineering, there is a need for laboratory spaces. However, the ergonomicis is not always high in the priority list when designing these spaces. Also the allowed budget sets boundaries for the planning and many needs have to be compromised.

Laboratory engineering students have a lot of laboratory work in their curriculum, even up to half of their studies. Also after graduation, they typically work in various research institutes, governmental laboratories, industrial laboratories, including the pharmaceutical, food, wood processing and chemical industry laboratories, as well as in environmental and life science research laboratories. To them, laboratory work sometimes means awkward working postures and for long periods of time. To prevent work-related musculoskeletal disorders and to lengthen work careers in the long run, good posture and good workplace ergonomics are important aspects for

them. Both theoretical knowledge of good workplace ergonomics and practical own experience of it, not only help them themselves, but also benefit their whole work community when they work in managerial positions.

In this study, we concentrate on ergonomics in chemistry laboratory work in Tampere University of Applies Sciences from the physical factors point of view in two different laboratories: biochemistry (Fig. 1A) and instrumental analysis (Fig. 1B). In instrumental analysis lab, the students for example need to prepare the standard solutions and experimental samples and carry out analyses using different spectrometers and other intsruments, like HPLC, GC-MS, UV/Vis, TOC, AAS etc. In biochemistry lab, the working is more manual, less static, and contains a lot of precise hand working and pipeting in many consecutive sequences. Due to differences in working, these two laboratories were chosen for this research to have more complete view to ergonomics.

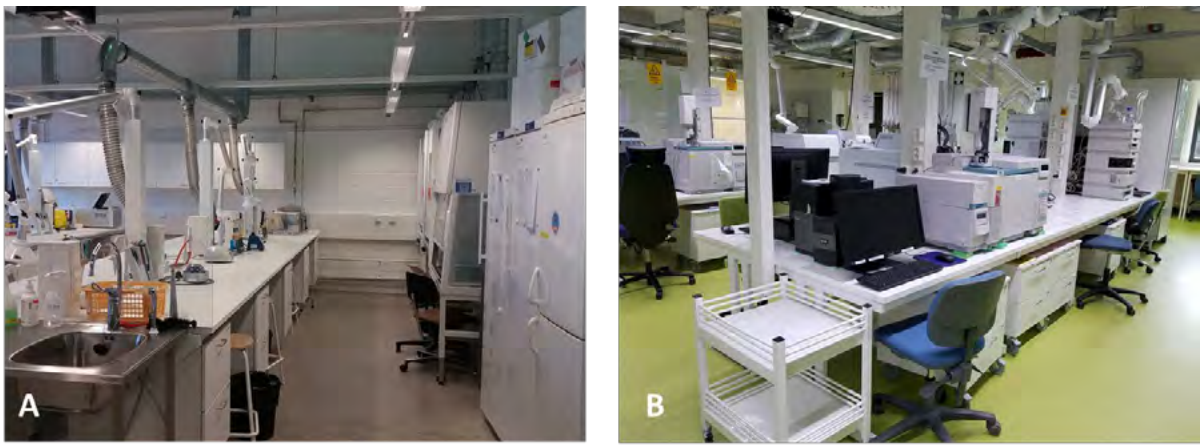

Fig. 1. A) Biochemistry laboratory and B) Instumental analysis laboratory.

1.3 Wearable posture sensors

Nowadays people are repetitively bending their heads over smart phones, handheld devices and laptops. This can lead to increased stresses in the cervical spine area and eventually to a “text neck” problem [6]. However, the development of wearable sensors and smart phone apps can also help in this same problem. There are several posture sensors on the market. The idea in posture sensors is to measure the tilt angle of upper back or neck and use it as a marker for bad/good posture. Many of the sensors have also a training mode, in which the sensor gives haptic feedback (e.g. vibrates) when the person is in slouched posture. In a pilot study by Zheng & Morrell, 100% of the subject persons sat in upright posture more often when there was haptic feedback than when there was not [5]. Additionally, when they turned the feedback off, all of the subjects continued to sit in upright or near-upright postures. Thus, haptic feedback seems to work well when training good posture for better ergonomics. Also Peper et. al. found that wearable posture feedback device helped participants to improve posture and decreased symptoms [7]

2 METHODOLOGY

2.1 Outline of this study

The main idea in this study was to observe the laboratory ergonomics in biochemistry and insrymental analysis laboratories. Naturally the students also got information about their own working in the laboratory from the ergonomics point of view. This was accomplished with three different methdos:

1) Laboratory engineering students were using wearable posture sensors during the laboratory work days for two weeks.
2) Students from physiotherapy degree program participated in the study by observing the working in the laboratories and carrying out ergonomics mapping of the laboratory spaces.
3) The laboratory engineering students, laboratory personnel and teachers were interviewed and the students surveyed with an online form about their experiences of the ergonomics and using wearable sensors.

2.2 Collecting sensory data

In this study, ”Upright Go” -posture sensors were used to investigate the ergonomics in two different chemistry laboratories in Tampere University of Applied Sciences. The volunteer students were asked to wear the wearable sensors during their laboratory work for two weeks. The students attached the sensors to the their upper backs with medical-grade silicone tape in the beginning of each laboratory work day (Fig. 2A). The students used their own smart phones to connect to the wearable sensor and to collect the data and sent the data to the researchers afterwards. Prior to the data collection, the sensors were calibrated while in good posture in the guidance of the physiotherapy students. Altogether there were 15 laboratory engineering students who volunteered to join in this research.

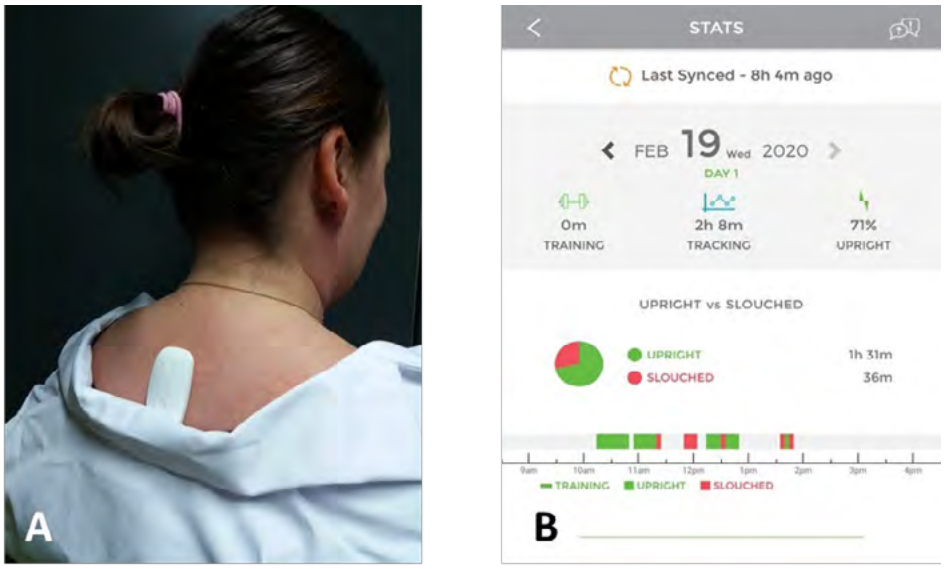

Fig. 2. The sensor attached to upper back (A) and the view to data in “Upright Go”-app (B).

The data consists of temporal distribution of the times of having a good posture and a slouching posture, respectively (Fig. 2B). The Upright Go app stores the time in slouched posture only after 3 min delay to allow movements etc. without recording them. It should be noted, that the initial positioning and calibration of the sensor affects all results and therefore these tasks were accomplished in guidance by the physiotherapy students. In this study, sensor's haptic deedback was turned off, because the main idea was to measure the posture and investigate the laboratory ergonomics, not yet train the students for better postures.

2.3 Interviews

While carrying out the ergonomic mapping of the laboratory spaces, the physiotherapy students also interviewed the students about their experiences of ergonomics. Afterwards a short online survey form was sent to the students who participated in this research. There were 8 answers (73 % of the participants) to the survey. All of the questions were open ended:

1. "*What do you think laboratory ergonomics means?"*
2. *"How did you experience this ergonomics research in general?"*
3. "*How did you experience using the Upright Go sensor?"*
4. *"From an ergonomic point of view, did you notice any differences between the intstrumental analysis lab and the biochemistry lab?"*
5. *" How would you like ergonomics to be taken into account in your studies in general and in your laboratory work in particular?"*
6. *"This study did not (yet) actually guide you to ergonomic work, but was this study already of any benefit to you yourself?"*

3 RESULTS

3.1 Posture sensor data

Figure 3 shows the sensor data of all laboratory working in the two different laboratories. Each horizontal bar represents one student visit to a laboratory. Some of the students worked more than one day in the labs during the research period and therefore there are more lines than volunteer students. The data bars are in random order. Clearly, there is a lot of variation between students, some showing upright posture almost all day long, whereas others had been in slouched posture most of the lab time. Especially in biochemistry labs there are some students who had spent most of the time slouched. In instrumental analysis lab, the situation is not quite as bad as in biochemistry lab.

The distributions of the times that students had spent in slouched posture in the two laboratories are presented in Fig. 4 as box-whisker plot. The same observation as before can be made here: In biochemistry lab students had spent more time in slouched posture, someone even over 200 minutes. This is remarkable part of the working time, which on average was 255 min in that laboratory.

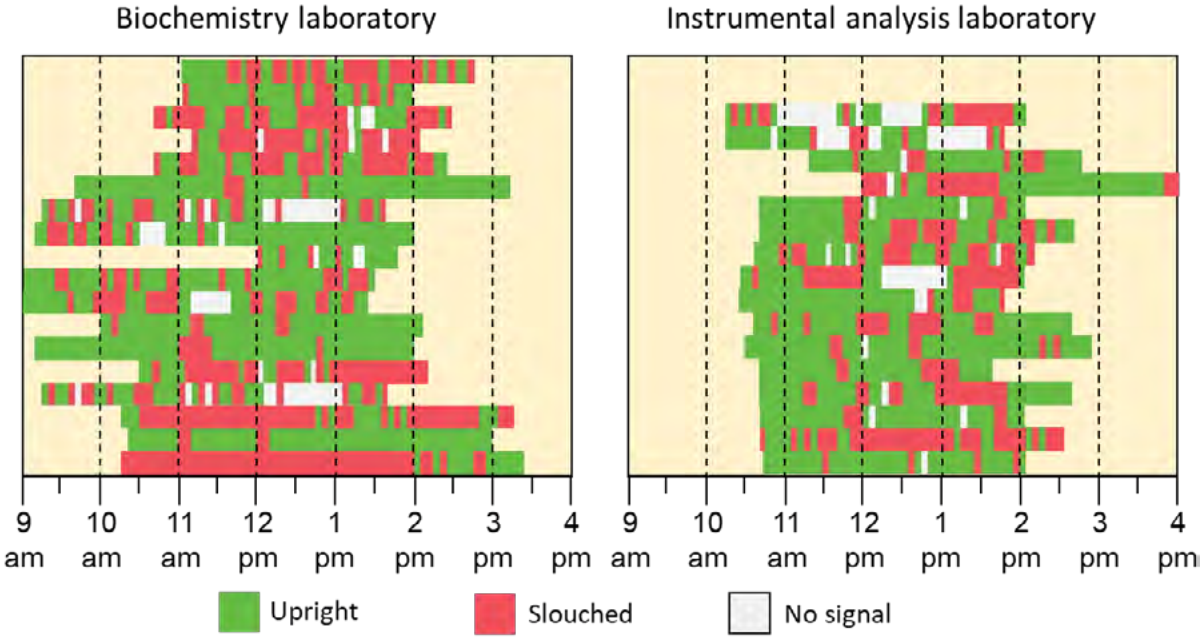

Fig. 3. Sensor data of all laboratory working in the two different laboratories. Each horizontal bar represents one student visit to a laboratory.

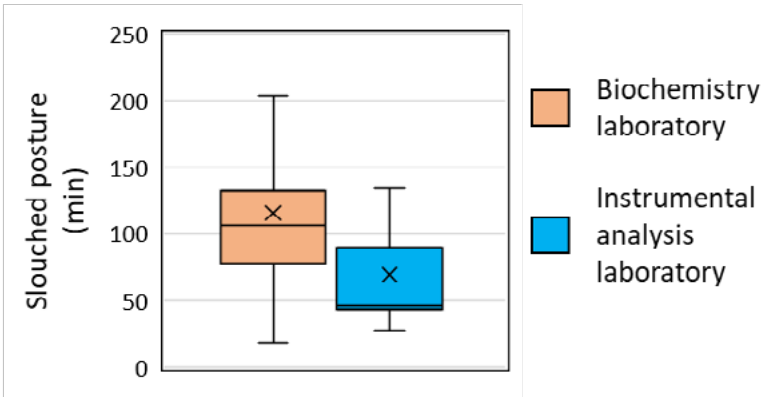

Fig.4. Temporal distributions of the times students had spent in slouched posture in biochemistry laboratory and instrumental analysis laboratory.

It can be speculated, that the posture is more likely to be slouched after long working time in the laboratory due to fatigue. If this was the case, then the sensor data wouldn't tell about the laboratory learning environment but rather about student tiredness. However, this can not be observed in Fig. 3. To investigate this further, a plot of slouched time percentage versus total laboratory working time was drawn. According to this graph (Fig. 5.) there is no correlation between the length of laboratory working time and slouching, neither in biochemistry nor in instrumental analysis laboratory, since the correlation coefficients are very low (r = 0,09 and r = 0,02. This supports the interpretation, that the slouching is caused by the laboratory work environment rather than fatigue.

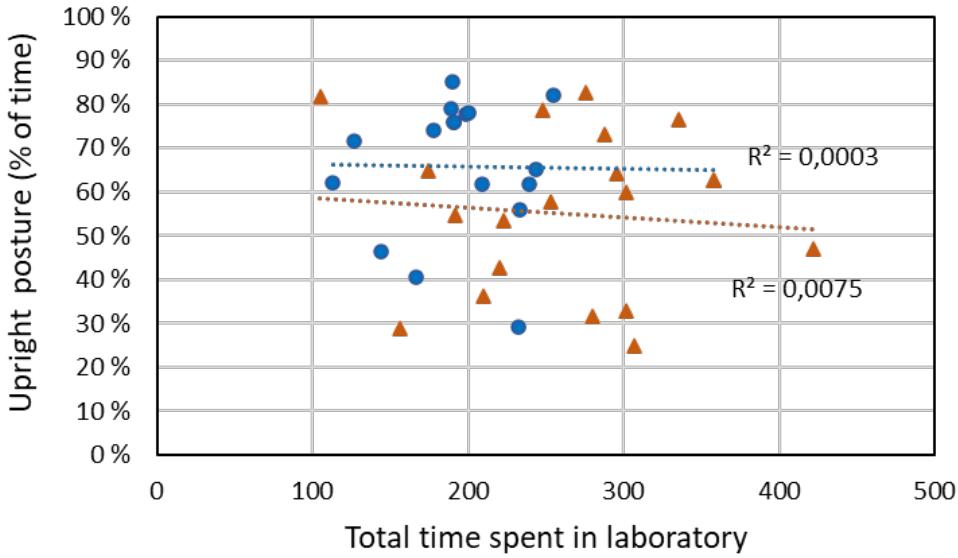

Fig. 5. There is no correlation between upright posture and total time spent in laboratory.

3.2 Ergonomic mapping, intreviews and survey

In the intreviews, many of students told about occasional pain in lower back and sholders. They told that the stools are not good and even the shorter students found the tables to be too low. According to the mapping done by the physiotherapy students, the tables were clearly too low for most of the students for standing work and the stools too high for sitting work for most students. The need for precise working leads easily to leaning forwards and tilting head (fig. 6A). Another problem arises with the fume hoods. There is no room for legs under the hoods which lead to very awckward postures (fig. 6B).

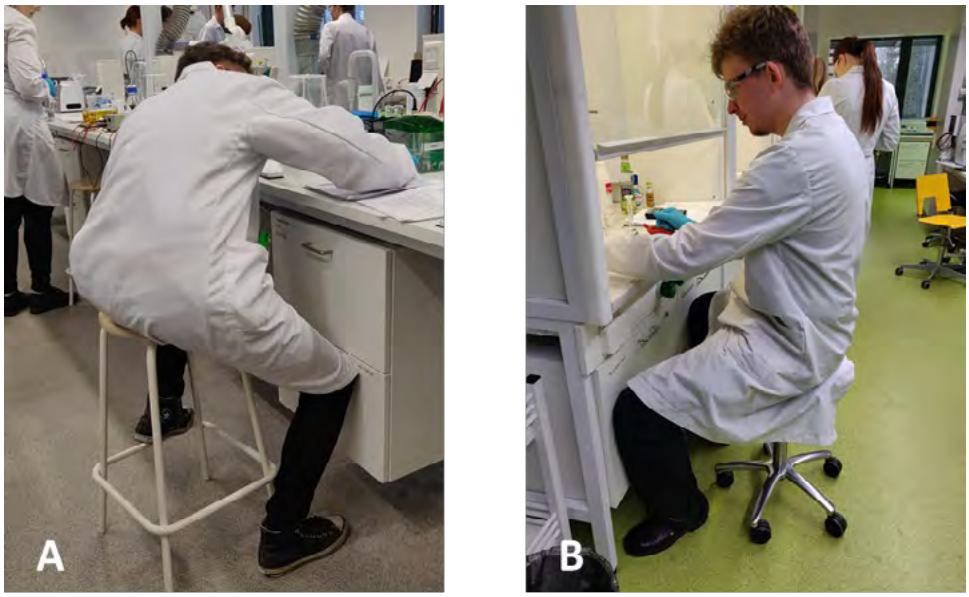

Fig. 6. A) The tables are too low for standing work and the stools too high for sitting work for most students. The need for precise working leads easily to leaning forwards and tilting head. B) There is no room for legs under the fume hoods which lead to very awckward postures.

According to the survey answers, all students found this ergonomics research to be interesting and important. Also the use of “Upright Go” -sensor was mostly found to be easy and undisturbing. Some students reported that in the beginning they were too aware of the sensors, which was somewhat annoying, but they forgot its presence after a while. Even though there was no posture training nor any ergonomics teaching for the students, all of the respondents answered that they already benefitted from the research by becoming more avare of their working posture and started to pay more attention to it. Here are a few picks from the student answers to the survey (translated to English):

> *”For the first time I started even to think about laboratory work ergonomics. For sure it would be necessary to pay more attention to it in the future.”*
>
> *“I hope that the different heights of students would be better taken into account. Electric tables would help. Ergonomics and its importance should be discussed more in the university.”*
>
> *“During this research project I have started to think about my working postures and how I could do the tasks with minimal physical strain.”*

4 SUMMARY AND ACKNOWLEDGMENTS

The Upright Go sensor was easy to use and students considered it undisturbing during the laboratory work. The initial positioning and calibration of the sensor is critical. The data revealed that many of the students worked prolonged times in sloughed postures. Thus, improvements need to be done both on the laboratory set-ups and furniture as well as in students working habits. The whole research also revealed, that laboratory work ergonomics is not well known by the students and they don’t pay much attention to it. In the future, some studies of ergonomics will be included in laboratory engineering curriculum. What comes to this research, in the next phase more volunteer students are needed for better statistics. Then the students can also be devided into experimental group and control group. The experimental group will then be trained for better postures and work ergonomics. By comparing their data with the data of control group, we hope to see the effectiveness of the training.

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INTEGRATED INTRODUCTORY PHYSICS LABORATORY COURSE ONLINE

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Conference Key Areas: *Physics in EE, Online learning*
Keywords: *Introductory physics laboratory, Online laboratory, Online learning*

ABSTRACT

Introductory engineering physics has traditionally included some laboratory work either as own laboratory course or as a part of theory courses. Generally, students are interested in active doing in laboratory, but calculations and reporting are often seen as laborious and demanding.
Since 2015, challenges with reporting have been tackled in a bachelor level engineering education by offering an integrated course “Basics of measuring and reporting”, in which Physics-, Mathematics- and Communications teachers work together. The key idea of the course is to bring all necessary basic skills the student needs for measuring and reporting to one single integrated course. In spring 2019 an online pilot version of the integrated course was planned and implemented, followed by another in autumn 2019. Costly laboratory facilities are not necessary in the online implementations. Laboratory tasks, that are used as a basis of reporting, are possible to organize in such a way that equipment is available either at home or from local grocery store. In this way the course is also easy to offer in open university nationwide.
The online course itself, challenges and solutions of the online implementation are described. Students’ experience of online laboratory course is also reported, using student feedback data. The pros and cons from the teacher teams of the implementations was collected and reported. The results promising, so there are several online implementations running now on yearly basis.

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1 INTRODUCTION

1.1 The role, importance and challenges of lab work in Physics in EE

Traditional engineering curriculum includes introductory physics laboratories, either on their own course or integrated in the theory courses. Learning outcomes of the laboratory courses may include learning physics concepts more deeply (more conceptual approach) or learning measurements, data analysis and reporting (more engineering approach). Both approaches strongly support scientific thinking as a cornerstone of engineering. According to Holmes ad Wieman, laboratories that are designed to improve students' intellectual and experimental abilities offer great opportunities to improve experimentation, reasoning and critical thinking skills [1]. Students' experiences on introductory laboratory courses vary a lot and they depend on the goals an implementation of the laboratories. According to research, experiences in the laboratory can be negative or dull, because tasks, working and the solution methodology are pre-stated [2]. On the other hand, a survey from Australia have shown that students felt physics laboratory work useful, understandable, interesting and enjoyable. [3]

Typical difficulties that students encounter in introductory physics lab courses lie in understanding the measurements and interpreting the gathered data. Students may see the measured values as exact without any uncertainty [4]. The concepts and implementation of error analysis may be difficult for students even after the laboratory course [5].

One of the key learning outcomes in the introductory physics laboratories is the writing a technical, scientific report. According to student feedback it is often seen as the hardest part of the of a laboratory course. One good practice to reduce students' workload in reporting in "sElf" approach. In the approach students focus on different parts of the report on different tasks and only finally write a complete report with all parts included [6]. In Tampere University of Applied Sciences, the high step to scientific reporting has been smoothed with dividing physics laboratories in two courses. The first course, "Basics of Measuring and Reporting (3 cr)" is an integrated course in which students learn the very basics of measurement, data analysis, error analysis and reporting [7]. In the second course, "Laboratory Works of Physics (3 cr)", students practice their skills and finally the course ends to self-designed laboratory work which is reported either as a poster or a video [8].

1.2 Pressure and need for distance learning

Traditional way to implement introductory physics laboratory courses need reasonable laboratory facilities, that are often expensive and need more teachers per student group for safety reasons. In Finland, the national funding model of universities also encourages to open and distance learning, so there was a genuine need to arrange as much online teaching as possible. So "Basics of Measuring and Reporting was re-designed in a way that students are able to make the measurements at their homes with equipment that they find in their households or

with low costs at the local supermarket. The CoViD-19 pandemic really proved the need for this kind of innovative online solutions, in which students are able to work hands-on at their own home.

2 METHODOLOGY

2.1 Design of the online course vs. the traditional course

"Basics of Measuring and Reporting" in traditional or online implementation is students' very first course for making measurements and reports in Tampere UAS. It is an integrated introductory physics course with elements of physics, mathematics and communication. Integration means that skills needed for measuring and reporting are not taught in different separate physics, mathematics or communications courses but in a single integrated course. The idea of the integrated course is presented in fig. 1.

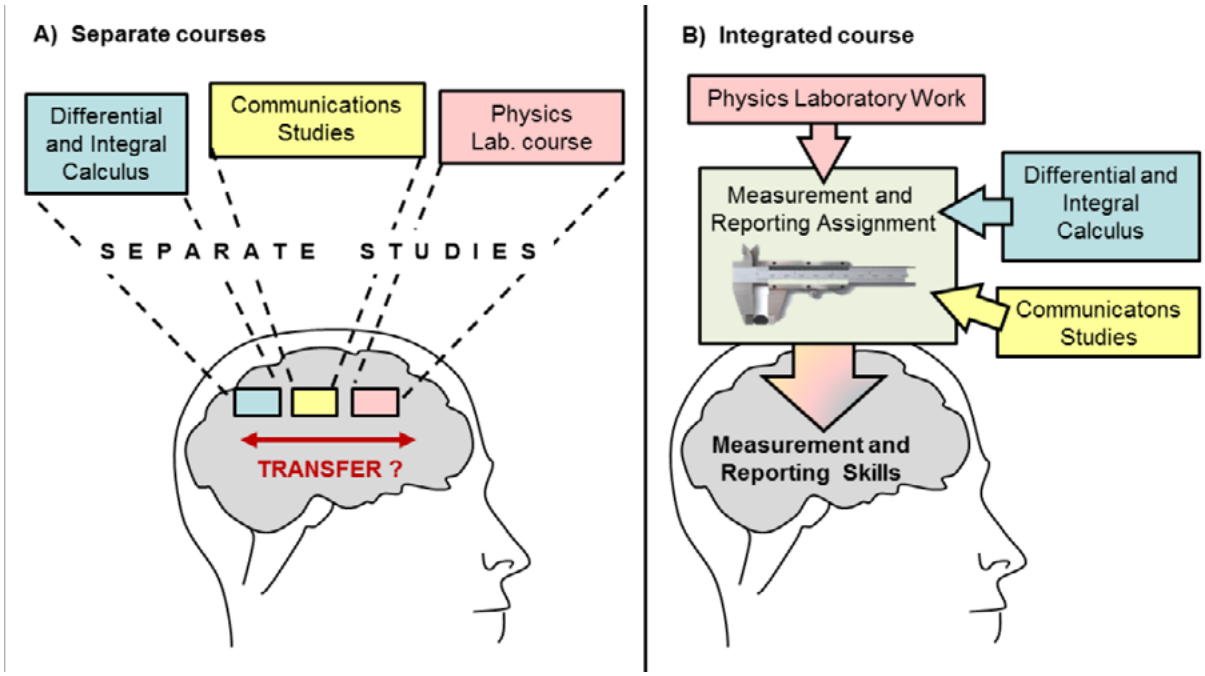

Fig. 1. The idea of the integrated course

"Basics of Measuring and Reporting" includes following learning outcomes:
Student can:

- make a measurement task under supervision
- make a data sheet under supervision
- calculate the results of the measurement task
- make a graph representing the results
- make an appropriate error analysis
- draw up a report in accordance with standards

From the learning outcomes it is seen that students get a lot of support for their studying. The support is arranged in a way that there are three teachers, physics, mathematics and communications teacher guiding students in “Just in time” throughout the course. This means that student makes measurements under supervision and guidance of a physics teacher. After completing the measurements, student gets guidance for data- and error analysis from mathematics teacher. Finally, a communications teacher helps with the reporting. The course includes three laboratory tasks to complete.
In a traditional course, the measurements are carried out in physics laboratory and they are followed with a workshop of mathematics and a workshop of communications. Each of these phases lasts one week so there can be three different student groups at the same time slot for a single teacher team (fig. 2.).

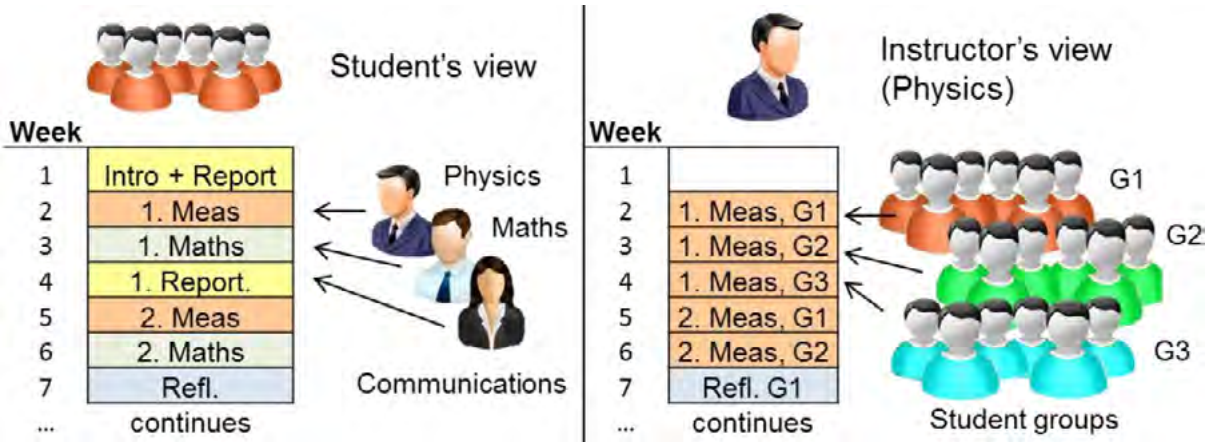

Fig. 2. Traditional course

The traditional version of the course is heavily scheduled with measurement tasks and workshops of mathematics and communications.
Online learning typically includes more independency for students in their time management. The online course follows the guidelines of the traditional course. First measurements, then data-analysis and error analysis, followed by reporting. But it is scheduled only with deadlines for measurement task and reporting task.
Measurements must be chosen in a way that the risk of injury of a student is minimal and the equipment needed is found from their households or with a low cost from a local supermarket. The guidance, “just in time”, lies heavily on instructions and videos. Online live sessions of measurements, mathematics and communications are also available.

2.2 Implementation of the online version

Online version of “Basics of Measuring and Reporting” was built on Moodle platform. The structure of the course on the platform followed the design of the traditional implementation, three measurement tasks with mathematics and communications support. Each task included clearly the support for measurements, the support of

mathematics and the support of reporting. The support and instructions of reporting were also at their own section at the end of the course platform.
The measurement tasks of the online course included.

- The effect of the accuracy of the measurement device, density
- Spring constant of a rubber band
- Acceleration due gravity

In the first task students were asked to pick up an object, to measure its dimensions and weight with error estimations. Students calculated the density of the object with the error estimations using the relative uncertainty method. The equipment for measuring the dimensions is usually found at home and scale if not at home, at the closest supermarket.
In the second task students determined the spring constant of a rubber band. The students were encouraged to use a measurement setup described in fig. 3. The tension of the band is easy to adjust with water.

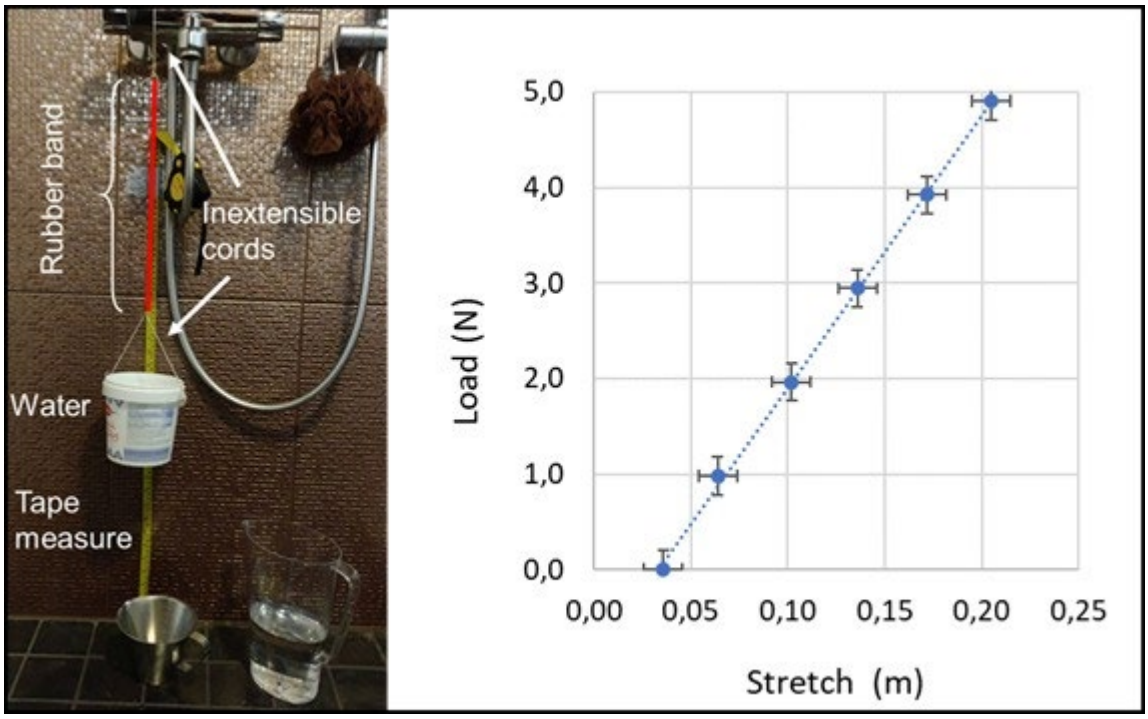

Fig. 3. Measurement setup and example graph

In the second task students were asked to draw an appropriate graph and to calculate the spring constant using linear fit to their data.
In the third task the students determined local acceleration due gravity by dropping object from different heights. Acoustic stopwatch of the PhyPhox app was used for measuring the falling times. Measurement setup is described in fig. 4.

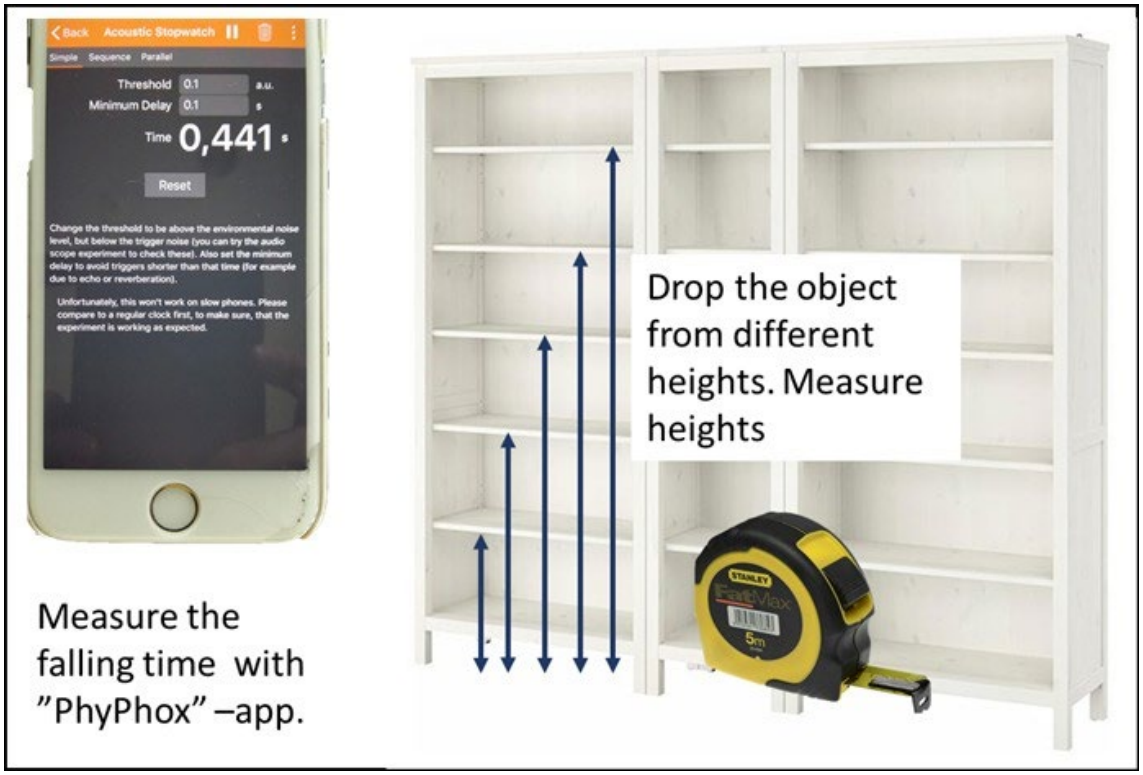

Fig. 4. Measurement setup for local g

The data analysis and the error analysis were made with two different methods, linear regression and calculations with partial derivations. A sample data with a sample graph is presented in fig. 5.

t (s)	y (m)	Δy (m)
0,32000	0,487	0,002
0,41550	0,808	0,004
0,48800	1,127	0,0035
0,54975	1,444	0,005
0,59825	1,718	0,002

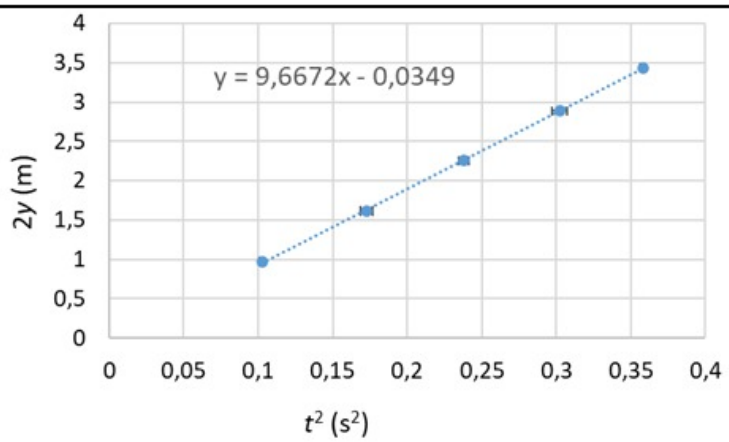

Fig. 5. Sample data and sample graph

2.3 Data gathering

Online version of the "Basics of Measuring and Reporting" has had three implementations. Teacher teams of the implementations (5 persons) were shortly asked to tell their pros and cons of the online implementation and their development

ideas. Students' opinions of the online course were collected from student feedback and a short similar questions with ongoing implementation (13 answers).

3 RESULTS

3.1 Online implementation from teachers' perspective

Pros and cons from the teacher teams are described in table 1.

Table 1. Pros and cons from teacher teams

Pros	Cons
• Stronger time independency for both, students and teachers • Students' greater responsibility for their work	• More difficult to give feedback just in time if students don't ask for it • A lack of peer support and social pressure among students • Overall quality is poorer

Teacher teams described that the online implementation required more preparatory work compared to the traditional one. Student guidance was mainly based on written feedback, because the online discussions were in minor use. Therefore, the written feedback must be very accurate. In written feedback, discussion of different options is often missing, because the normal social contact is only online. In online implementation, students have to take more responsibility on their own work because the support is not pre-scheduled like in traditional courses. There were a lot of more dropouts in online implementations compared to traditional ones. Overall teacher teams strongly support the online possibility of the course.

3.2 Online implementation from students' perspective

Pros and cons from the students' perspective are described in table 2.

Table 2. Pros and cons from teacher students' perspective

Pros	Cons
• Stronger time independency • Necessary information is always available • Designing own measurements	• Measurements made at home may not be as interesting as in laboratory • IN traditional laboratory students get immediate feedback from their measurement • Live online support only at announced times • Lack of contact with other students

According the student feedback success in online course needs accurate following of instructions and independent time management. Students' development ideas for the course included some more time slots for online sessions and some improvements and examples for instructions available either on video or in written form.

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TOWARDS AN EMOTIONS-BASED ENGINEERING ETHICS EDUCATION

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Conference Key Areas: *Sustainability and ethics, Interdisciplinary engineering education*
Keywords: *Emotions, Ethics, Power, Empathy*

ABSTRACT

Mainstream engineering ethics education focuses on the thinking processes that contribute to ethical decision making, rather than on the feeling processes. For example, major engineering ethics textbooks, tend to focus on different philosophical approaches to thinking through ethical dilemmas (Utilitarianism, Deontology etc.). Although emotionally-based alternative approaches (such as a feminist care ethics) are sometimes treated in passing they are not fundamental to the way in which the discipline is framed in these texts (which act as the major framework for many engineering ethics teachers). Although there has been some discussion in the wider literature about the relationship between emotions, risk, and ethics there has been a limited amount of empirical work in this vein.

Within the psychology and sociology of ethics, emotions are increasingly ascribed an important role, including a focus on 'moral emotions', and Haidt has argued that it is emotional responses, rather than rational processes, which often drive what is seen by the person as 'the right thing to do'. A sociological and psychological take on emotions also bring a range of other concepts into focus in thinking about engineering ethics, including notions of power, identity, responsibility, practices, and context. An emotions-based approach need not mean discounting ethical reasoning, but rather locating it in a whole-person context that includes thoughts, feelings, and the body.

This conceptual paper will explore what an emotions-based approach to engineering ethics means, and the implications of this for how engineering ethics are taught and learned.

1 INTRODUCTION

Mainstream engineering ethics education tends to focus on the *thinking processes* that contribute to ethical decision making, rather than on *emotional processes*. Looking, for example at major engineering textbooks, Van de Poel and Royakkers [1] define ethics as "the systemic reflection on what is moral". They move on to describe ethics as being underpinned by three primary ethical theories (consequentialism, deontology and virtue ethics). While 'care ethics' is described in a short section, attempts to develop a care ethics in engineering is described as being "in its infancy" and notions of 'care' are rarely used in any significant way in the rest of the text. The word 'emotion' appears only 4 times in the whole book and is not related in any systematic way to ethics. The word empathy does not appear at all. Other mainstream textbooks also mention emotion and empathy at most in passing but do not treat them in any serious way.

This is surprising, given that emotions has grown to have an important role in academic discussions about moral action. In psychology and in sociology, the emotional revolution began in the 1980s and gained considerable ground in the 1990s. The growing academic interest in emotions was associated with a change in how emotions were understood in popular culture. While, throughout much of the history of western thought, emotions were understood principally as being a 'threat to reason' and as "much more primitive, less intelligent, more bestial, less dependable, and more dangerous than reason, and thus [needing] to be controlled by reason" [2], from the 1990s onwards emotions came to be framed in more positive ways, and in scientific and popular science literature became linked to 'intelligence' (Daniel Goldman), to rational decision making (António Damásio), and to success in social life and organisations (Frans de Waal). Part of this re-conceptualisation was the shifting of interest in moral psychology from a focus on moral reasoning to a focus on moral emotions [3,4].

This paper reviews recent literature on 'emotions' and 'engineering ethics education'. It ends by highlighting some ideas as to how engineering ethics education can pivot towards a more emotionally-based (and perhaps more effective) approach.

2 METHODOLOGY

This paper is based on a review of literature in major engineering education journals (*Journal of Engineering Education* and *European Journal of Engineering Education* and *Science and Engineering Ethics*). Searches were carried out for articles which included references to "emotion*", "empath*" and for articles which referenced (a) both "ethic*" AND "emotion*" or (b) both "ethic*" AND "empath*".

This limited review was followed by a wider non-systematic, review of literature on 'emotion' and 'engineering ethics' and 'education'.

3 EMOTION, ETHICS AND ENGINEERING EDUCATION

3.1 What is 'emotion' and which emotions are 'moral'?

Historically, emotions were conceived of as being in contradistinction to rationality. If lay theories of emotion have not moved far from this, contemporary empirical literature has moved beyond this separation such that emotions can be defined as a "complex, multicomponent episode that creates a readiness to act" [5].

Emotional episodes are typically understood as occurring in the context of a particular person-environment relationship. The environment in this case may be the physical environment but is often the social environment – emotions play a role in locating us with respect to others [7]. Within this context, the multiple components of an emotional episode include (i) cognitive appraisal of the person-environment relationship, (ii) a subjective appraisal of the situation which draws on both cultural resources and sense of identity, (iii) the disposition to think or act in particular ways, (iv) internal bodily changes (often linked to action dispositions), (v) facial expressions and (vi) responses to the emotion which may include acting on the environment, or on ourselves to regulate the emotion being experienced.

These components can be illustrated with a commonly recognised emotion such as anger: something happens in the social or physical environment which is cognitively appraised (i) as being unjust. This sense of injustice may be linked to social structures and hierarchies or to culture (ii). For example, an engineer may get angry if they are questioned closely about something within their area of expertise by a secretary, while the same questioning may not elicit anger if it came from a fellow engineer. Implicit in the emotion of anger is (iii) a disposition to act to 'right the wrong'. This action is prepared for through bodily changes (iv) such as an increase in adrenaline and an increase in breath and heart rate. Alongside this, the person's eyebrows are drawn down and together and their upper lip contracts (v). The person then responds in some way to this experience (vi), perhaps by re-thinking whether the secretary actually has expertise that the engineer had not anticipated, or by telling the secretary to stick to his or her own business. This response feeds back into and changes the ongoing emotion episode. The 'emotion' is not simply the bio-physical or subjective ('feeling') element of this process – emotion is the whole package which has to be understood simultaneously as social, cultural, bio-physical, and cognitive.

In this sense, emotions are not separate from cognition in the way in which they have typically been imagined in western thought. Cognitive appraisals (labelling a question as "insulting" or "insightful") are intrinsic to how an emotion episode develops, while emotion regulation decisions are a result of emotional metacognition. Emotional bodily sensations also provide information to cognitive systems about our primary (pre-cognitive) appraisal of situations (e.g. one can have heightened awareness associated with fear before being consciously aware of what it is that one is frightened of, for example). This interlinking of 'cognitive' and 'feeling' is the origin of the idea of 'emotional intelligence', defined by the Yale team who coined the term

as the ability to perceive emotions in the self (congruence) and in others (empathy), to understand emotions (e.g. having a rich emotional vocabulary and identifying how emotions relate to each other, blend and change) and to use them to achieve goals, and to regulate emotions in the self and others [6] (since the term 'intelligence' is such a loaded one, these abilities are referred to here as 'emotional competences'). It is notable that empathy – framed here as a perspective-taking ability – is a core component of emotional competences, but emotional competences are framed here as wider than empathy.

Engineering ethics is commonly discussed in terms of social organisation with micro, meso, and macroethics issues corresponding to the micro, meso and macro levels of sociological study. If cognition is intrinsic to emotion, so too is social organisation. In the example above, the perceived social position of the questioner *vis a vis* the engineer contributes to development of anger. Jenkins and Oatley propose that emotions locate us in relation to other people across three dimenisons depending on whether relationships give us a sense of Affiliation (warmth/affection), Attachment (safety/security), and Assertion (power or position within a social hierarchy) [7, p. 229]. Thus, feeling angry indicates a sense having a higher status or a sense of power with respect to another, while feeling shame indicates a sense of lower status or power (the Assertion dimension). On the Attachment dimension, feeling anxious or feeling trust indicates respectively a high or low distance from another, while on the Affiliation, feeling warmth towards or cold towards other people reflects a lesser or greater social distance.

At a superficial level it is easy to see that emotions give us a sense that something is 'good' or 'bad' and that they are therefore providing us with information which is profoundly connected to ethics. While there is a common sense focus on the valence of emotions (positive vs negative) it would be wrong to assume that negatively valenced emotions are morally unhelpful. Anger, for example, is described by Haidt [3, p. 856] as "perhaps the most underappreciated moral emotion", with moral emotions being defined as "those emotions that are linked to the interests or welfare either of society as a whole or at least of persons other than the judge or agent" [p.853]. Anger is one of a family of what Haidt describes as 'other condemning' moral emotions, along with contempt and disgust. Other important moral emotions include shame, embarrassment, guilt and pride (the self-conscious family), empathetic distress (other-suffering family), and gratitude and awe (other-praising family). It is worth noting that the term 'empathy' is used here again, but in a different sense (now an emotion rather than a cognitive competence). Empathic distress at another's distress is identified as a crucially important moral emotion [8, 22], however the set of moral emotions is much wider than empathetic distress alone.

Viewed from an 'emotional competence' viewpoint, an emotion like anger is providing the person with information about an appraisal of injustice. However the component model of emotion highlights that anger does more than provide

information, it also generates thought-action tendancies and changed bodily states which may dispose a person towards more risky and careless decisions, something which may make it harder for people to engage in ethical reasoning processes [21]. Attending to emotional information is therefore, not enough. There is also a need to regulate emotion.

3.2 'Emotion' and 'Ethics' in Engineering Education literature

As was noted above, emotions are rarely substantively referenced in mainstream enignering ethics textbooks. In the engineering education research literature a focus on emotions has only begun to emerge in recent years.

In the last twenty years there has been some philosophical work on emotion in engineering ethics [for example 9, 10, 11] and, in line with the 'moral emotions' arguments developed in moral psychology, it has been claimed that "rather than being biases that threaten objectivity and rationality in thinking about acceptable risks, emotions contribute to a correct understanding of the moral acceptability of a hazard" [9, p.107]. This has led to arguments that engineers should be taught to accept the emotional dimensions of engineering, to use their discomfort to identify ethical issues, to think of their gut intuitions as a useful but unreliable sensor, and to practice linking 'reasonable' emotions to arguments [11]. It is worth noting that this framework follows the Yale model of emotional intelligence (as described above).

Among the first to look at what this might mean in practical terms in engineering ethics education is Theil et al. [12]. Noting that case studies are suitable for and widely used in engineering education, they argued that most cases are devoid of emotional content. They hypothesised that including information about the emotional responses of the case's primary character would facilitate retention and transfer of the case's knowledge content. Quantitiative analysis of performance of 126 research participants indicated that recall of ethical cases was better when emotional content was included, as was performance on a transfer task. The focus here is on better learning of cognitive ethical content though emotional engagement, rather than on the development of emotional competences per se.

Sunderland [13] also provides a detailed account of integration of emotions-based ethical work into engineering education, this time through a PBL methodology. PBL's focus on complex and ill-bounded problems is identified as making it it highly suitable for ethics education. In a 'story sharing' activity, students are asked to respond to 'technology in the news' stories emotively, as well as pre-reflectively, and reflectively. Emotional responses allow students to identify what is meaningful for them (and presumably to become aware of and find a language for their own emotional responses and those of others). Accounts of students learning are presented but described as preliminary. Furthermore while this work highlights the importance of 'emotion', there is little specific focus on particular emotions (guilt, pride, awe, joy, empathetic distress) or on a model of what emotional skills or knowledge were to be developed.

It was noted above that the concept of empathy is closely linked to that of emotion, and that empathetic distress is a fundamental moral emotion. More broadly, the concept of empathy has been used in engineering discourse over the last two decades. While this has often been in the context of 'empathy work' within the design process, empathy has also been linked to engineering ethics.

Walther and colleagues begin from a recognition that there is a "scarcity of conceptual models and empirical bases that limit the broader integration of empathy into the discussion and practices of engineering educators" [15, p.12; see also 16, p 535]. Inspired by exchanges with colleagues in Social Work education, Walther and colleages seek to address these gaps by the development of a conceptual model of empathy as a learnable skill built on affective sharing, awareness of self and others, perspective taking, emotion regulation and the ability to metacognitively switch between analytical and empathetic modes. This is framed both within a professional practice orientation (which includes an understanding of micro, meso, and macrosocial systems) and a professional identity or 'way of being', which includes a focus on service to society [14]. This model moves beyond the more narrow definitions of empathy described above (and below) to treat empathy as a broad space in which to articulate a range of emotional competences. In later empirical work, they describe a facilitated experiential learning approach for developing empathy in engineering students and highlight how questions of social distance and of power/responsibility (questions which are encoded in emotional episodes) play out in students' work in developing empathy skills. They also provide rich descriptions of students experiencing moral emotions such as pride, shame and distress at the distress of others [15]. While there is no systematic measurement of learning gains in comparison to a control group, rich and rigorously analysed qualitative accounts of learning from over 100 student participants are provided.

Hess and colleagues also focus on empathy and the related concept of care. The model of empathy which they use is more restricted than that of Walther and colleagues and frames empathy in terms a cognitive and emotional dimension and a self- and other-focused dimension [16]. They identify empathetic perspective-taking – a cognitive aspect of empathy – as a core skill, and note that at present there is little evidence about the processes that promote the empathic formation of students. Utilising the Scaffolded, Interactive, and Reflective Analysis (SIRA) framwork [17], they describe integrating empathetic perspective-taking into a case study method to ethics teaching based on a Reflective Principalism approach. In their model, students first establish knowledge about the case, then engage in perspective taking before comparing and contrasting their perspective-taking work with other students. Thereafter they move on to decision-making followed by a meta-reflection. Qualitative interview-based data was collected from 19 participants. The interviews suggested that opportunities to share perspectives with others were important in the development of perspective-taking skills, including those which gave rise to a realisation that others viewed things in a different way – or indeed, in the same way but for different reasons. Although there is no control condition, participants did

claim a heightened ability to take perspectives and an ability to take perspectives of a wider range of stakeholders. In another study the same research team evaluated the impact of the SIRA approach using a number of quantitative measures of ethical reasoning as well as the Interpersonal Reactivity Index (IRI) to assess a number of dimensions of empathy [17]. Although participant numbers were not large (29 in test group) they did find statistically significant increases in empathetic perspective-taking and, based on a reduction in empathetic distress, they inferred that students also developed enhanced emotion regulation skills.

Gelfand [18] argues that moral psychology research has highlighted a number of features of ethical behaviour that are not typically addressed in 'moral reasoning' type courses. These include prior emotion or mood of the person, their available self-control resources, bystander effects, and dual systems thinking processes and associated routinized behavours as well as primary (emotional) appraisals. As a result, he argues that existing ethics education approaches should be augmented by study of moral psychology and by the development of metacognitive abilities such that people can better regulate when and how to make ethical judgements. He describes doing this through using case studies of research findings presented alongside 'emotional coping' strategies. There is no data presented on the impact of this approach on student learning.

Steele and colleagues [19] and Higgs and colleagues [20] both worked within an Ethical Sensemaking approach which aims to include emotion within the ethical decision making process. For Steele, meta-cognitive emotion regulation was included as a strategy, along with a focus on situational and cognitive biases, in ethics training offered to students across a range of disciplines, including engineering. Using a pre-existing Ethical Decision Making measure (EDM) they evaluated the impact of their two-day research ethics training workshop on 127 participants and found significant increases in scores across a range of ethical strategies measures including 'dealing with emotions'. Higgs and colleagues [20] looked specifically at the experience of guilt, shame and embarrassment and its impact on moral decision making. Using an experimental design they used multiple versions of the same case study in order to generate the required emotions. They then looked at the impact of these emotions on participants' ethical decision making. They found that emotions of guilt and shame each changed the perceptions of the dilemma in question. Participants who felt shame, for example, reported highest levels of personal responsibility while those who felt guilt saw the problem as more pressing. They note, "contrary to common thought, experiencing no emotion while in an ethical dilemma may actually result in cognitive processes that could lead to less ethical decisions" [20, p.53]. Interestingly, they also found in their 1-hour long intervention that a structured approach to emotion regulation actually led to reduced use of metacognitive strategies and a reduction in sense of moral intensity. They suggest that this may be because the cognitive load induced by cognitive reappraisal may have hindered ethical sensemaking.

4 TOWARDS AN EMOTIONS-BASED ENGINEERING ETHICS

A review of the evidence on the role of emotions in engineering ethics education above suggests a number of directions that can be pursued in developing an effective, emotions-based approach.

First, much of the most interesting work in the field is emerging from interdisciplinary collaborations such as when engineering educators work with nursing educators, psychotherapists or social workers [e.g. 15]. These disciplines have a long history of work on developing emotional competence and empathy in students and their pedagogical approaches may well be adaptable to engineering situations.

Second, at a minimum, the introduction of emotional information into cases may have a positive impact on students retention and ability to apply what they have learned [12, 20]. However all emotions are not equal in this respect. There is some evidence in favour of a role for empathetic distress [22], guilt and shame [20] but not in favour of anger [21]. A greater focus on specific emotions may be more helpful than seeking to include 'emotions' in general.

Thirdly, most work proceeds on the basis that responding emotionally is not sufficient in itself, and that emotional information must contribute to an ethical reasoning process [e.g., 13,17]. This may mean, for example, emotively responding or perspective-taking early in the reasoning process followed by more 'cognitive' thinking strategies. However there is also evidence [20] that metacognitive emotion regulation strategies may also hinder effective ethical reasoning, at least if the total time available is short. Given the temporality of emotional episodes, spreading the ethical decision process over a longer period of time may be worth exploring.

Fourth, emotional competence skills (or 'empathy' as broadly defined by Walther and colleagues) may well help students to engage better in moral reasoning. However it is worth being clear as to what emotional competences are being targeted. The full range of emotional compences outlined, for example, in the Yale model [6], do not yet appear to have been integrated in any existing ethics intervention and the effects of learning to developing a range of emotional language, learning to recognise and name particular emotions in the self and others, learning about the effects of specific emotions on the body and on thought action tendancies, would be worth exploring.

Fifth, a range of pedagogies have been identified including (a) cases with emotional content, (b) including of 'perspective-taking' and 'perspective-comparing' stages during case analysis, (c) explicit teaching about cognitive and situational biases and emotion regulation strategies, and (d) experiential learning workshops focused on empathy skills. There is some initial evidence to support these strategies [12,17,19] but there are still far more questions than answers. Alongside the question of impact must be considered the question of measurement. There are a limited number of psychometric tools including emotional dimensions. Thus, development of appropriate assessment tools, and the use of rigorous qualitative methodologies, is a priority. This too will require interdisciplinary collaboration between engineering educators and those with expertise in social sciences.

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ON-LINE COURSE ON ENGINEERING MATHEMATICS: STUDENTS' EXPERIENCE WITH PILOT COURSE MATERIAL

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***Conference Key Areas**: Mathematics in the engineering curriculum, E-learning, open and online learning, blended learning, virtual reality*
***Keywords**: Erasmus+ Project, Engineering Mathematics, Online Course, Student Feedback*

ABSTRACT

Engineering marvels have enabled to have a better quality of human life and society needs an increasing number of engineers [1]. Common practice of higher education institutions is to incorporate mathematics knowledge and skills into engineering education [2].
This paper presents an alternative approach to fostering mathematics skills in engineering education: undergraduate student skill development in an online course created by an international team of academics. The purpose of this paper is to present the preliminary results of a pilot study of an engineering mathematics online

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course. This study draws on feedback questionnaires of students from Portugal, Spain, Poland, Romania and Estonia.
Preliminary results indicate that the students had very little experience with the subject covered before joining their class. They found the theoretical materials to be helpful and had little to no difficulties in understanding them. The practice tests were of high quality and offered a good feedback and were aligned with the theoretical materials. There was more than enough time to solve assessment tests and most felt that doing the assessment activities would help them both in the final assessment and in real life. Students found the materials easy to use as with nice graphics and not too much text. The platform was easy to navigate and the material presented in a logical, intuitive way. Some students felt the performance of used platform could be improved and it would be beneficial to add assessment tests from multiple subjects, not only for each section.

1 INTRODUCTION

1.1 International project

Mathematics and its associated subjects are fundamental elements of engineering education and an engineer is expected to demonstrate proficiency in the area. The contemporary skillset of undergraduates includes a degree of sophistication in the application of Information and Communication Technology (ICT) within their daily lives as well as within the higher education environment.
To meet these standards an ERASMUS+ project was launched. The project unites educators from six countries: the TTK University of Applied Sciences from Estonia (project coordinator), the Letterkenny Institute of Technology from Ireland, the Polytechnic Institute of Porto from Portugal, the University of the Basque Country from Spain, the Technical University of Cluj-Napoca from Romania and the Koszalin University of Technology from Poland. One of the main goals of the project is the development of a 3 ECTS engineering mathematics online course. The purpose of this paper is to present the preliminary results of a pilot study of an engineering mathematics online course.

1.2 Development of the online course in engineering mathematics

The project started with the identification of common mathematics topics and the discussion of modern pedagogical principles. Analysis of the structure and teaching specifications of subjects related to mathematics in partner's institutions has been developed. Due to several differences among all the partners' curricula including number of credits, period of teaching, different syllabus in similar subjects, different number of hours for one ECTS etc, the consortium has formulated a common core for all partners and possible particularities depending on the characteristics of the country or of the degree. The analysis showed that students had the same problems in the partner institutions. Students 'ICT readiness is taken for granted, but it hinders students' learning. Also cultural, linguistic and social barriers need to be considered. A common language of mathematics is expected to be necessary in intercultural

programs, but it is not enough. Course materials should be available in local language - sharing across borders is not easy. It needs to be ensured that local support measures consider local concerns. Automated assessment accounts only with the outcome of assessment, not the process. Smart assessment systems place a significant cognitive burden on assessors, assessment designers and students. The detailed overview with comparative needs analysis has been published 2019 [4]. The consortium has defined the aim of the online course as following: the aim is to develop basic knowledge and practical skills in the mathematical sub-area of Matrices, Determinants and Systems of Linear Equations related to Engineering. Direct target groups include students in engineering mathematics programs at higher educational institutions, academic staff teaching engineering mathematics in tertiary programs and research academics in the areas of technology-enhanced learning and on-line learning.

After the analysis of structure and teaching specifications of subjects related to mathematics, also characteristics and particularities of each partner's "system", and after discussing on which can be the most appropriate materials in each institution, the Portuguese team started developing of theoretical materials. It is anticipated that the interactive multimedia learning in mathematics can be a real support tool for promoting students' interest and involvement in learning through a variety of learning activities. The development process began with PowerPoint slides, which included an introduction, a background description, navigation and menu selection, and formative questions. Then the Portuguese team used the iSpring Suite 9 Software to introduce interactions, dynamic examples and exercises in the materials. In addition to correct answers to all the questions, a step-by-step solution was offered. The proposed solution is shown to students even in case they have found the right answer. With iSpring, the Portuguese team turned PowerPoint lessons into e-courses, producing 22 SCORM packages and uploading them for testing into Moodle platform. A comprehensive overview of the principles and workflow of creating learning materials was published in March 2020 [5].

The theoretical materials were supplemented by practical tests on the Moodle platform by the efforts of Estonian partners. A corresponding practice test has been created for each theory lesson, i.e. 22 practical tests have been created. Each test consists of 8-12 questions, depending on the theme. For variability each of these questions has in average 10 versions. Some versions of the question are created using the STACK question type, which generates the question with updated source data when the test is run. The question bank consists of 199 questions. So, in total considering the number of question’s versions there are at least 2000 items in question bank. There are 49 close-ended type questions and 150 open-ended type questions. Exhaustive feedback has been provided for each question.

Assessment materials are a consequence of previous activities which are very interrelated. Spanish team has created around 100 questions using the iSpring software. Due to some technical limitations as students could not see their grades on the assessment table on Moodle course, fill in gaps question type did not work

properly and partially true answers were considered incorrect, the Spanish team transferred assessment tests to Moodle platform instead of iSpring.
The content of on-line course was being initially developed in English, and then translated into the languages deemed appropriate to each partner in the project. Project was being implemented in several countries of Europe: Estonia, Ireland, Poland, Portugal, Romania and Spain. One of the wealth of Europe is its cultural diversity, languages included. Although we are using English as a core language, and if we want complete success in each country of the project, translation to local languages is definitely necessary. The translation of the main operational content of the output to the partners' languages is facilitating optimum implementation in all the involved countries.
In order to check the validity of the decisions made, it was decided to conduct a pilot course. The pilot courses in partner countries were performed between September 2019 and February 2020. In order to assess the quality of the course materials a study was done among students that took part in the pilot course.

2 METHODOLOGY

2.1 Questionnaire design and delivery

A survey method was selected for conducting the study. Beside the socio-demographics, questions were created to assess the student's interaction with the theory, practice and assessment materials. Most items used in the questionnaire used either 6-point or 7-point Likert scales. Students were asked to report their level of agreement with certain aspects of the course. Open ended questions were also asked to get customized feedback from students. Their open ended answers were analyzed by creating word clouds that evaluated the frequency of terms used by students. Common words that don't add value, called stop words (e.g. the, a, at, of, he, she) were removed prior to the analysis.
The questionnaire was created in English and them translated to the native languages and distributed to all partner universities. At the end of the pilot course students got the link to the online questionnaire and had to fill it in. Results were gathered by using a Google Form.

2.2 Sample description

At the time of analysis only results from Estonia, Poland, Spain, Portugal and Romania were available. A total of 95 students answered the survey.
Most students were from technical degrees (86 respondents) but also students from accounting and administration (9 respondents). Most students are young, with ages between 18 and 29 (86 respondents) but older students were also involved (ages 30 to 49 – 9 respondents). Romania had the widest spread from an age perspective. Most students had no prior experience in the course subject (44.2%), but students in some countries (Estonia, Poland and Romania) had more experience. All 8 Polish students had above average experience (scores of 4 and 5 on the 0 to 5 scale). Of the 20 Romanian students that answered the questionnaire, 12 had average experience (3 on a scale of 0 to 5) and 5 had above average experience and 5 out of

24 Estonian students had above average experience (scores of 4 and 5 on the 0 to 5 scale).

3 RESULTS

3.1 Analysis of responses

Students were asked if the theory is related to the material presented in class and if practice exercises and assessments are related to the theory. Most students found that the material is strongly related to class material. This was also true for the assessments and practice exercises. 80% and 82% of students respectively had high or very high level of agreement (ratings of 4 and 5).

Most students didn't have any difficulties at all with the material. 83% of respondents said that they had either no difficulties or very little (4 and 5 on the scale). Ten students did encounter difficulties, but each was specific without an identifiable pattern.

Students considered that they had either just the right amount of time or too much time for solving both practice exercises and during the assessment. 60% of respondents said they had just the right amount of time or slightly more (scores 3 and 4 on the scale) while 37% considered they had too much time.

Most respondents (85.6%) considered that this material will help them with the final exam (scores 4 or 5 on the scale). The distribution of answers was similar for theory, practice and assessment indicating that students consider them equally important towards their final evaluation.

Most respondents (81.4%) considered the material was moderately helpful for real life situations (scores 2,3,4 on the scale). Although they found it very useful for passing their exams, the feeling towards the material's usefulness in practice was not as strong. Students considered theoretical materials less useful in practice (14 answers of not useful at all to 10 answers for very useful) while considering practice (2 to 8) and assessment materials (3 to 8) as being useful.

Most respondents (87.4%) considered they had the right amount of materials (scores 2,3,4 on the scale). In the case of practice and assessment materials there were slightly more answers leaning towards too much materials (score 5 on the scale).

Most students (74%) agreed with the statement that the materials (theoretical, practice and assessment) were easy to use (values 4 and 5 on the scale), while 14% were moderately happy with the ease of use (score 3) and only 1% were completely dissatisfied with the ease of use. Values were distributed similarly for the theory, practice and assessment materials.

Most students (71%) liked the graphics in the theoretical material. The distribution of answers regarding the amount of text was quite uniform. There was little agreement if there was too much text in the material. Most found the platform to be intuitive (54%) and that it had a logical flow (78%). Most considered the platform easy to navigate (59%) and that they had enough information (86%). Scores of 4 and 5 were considered as agreement.

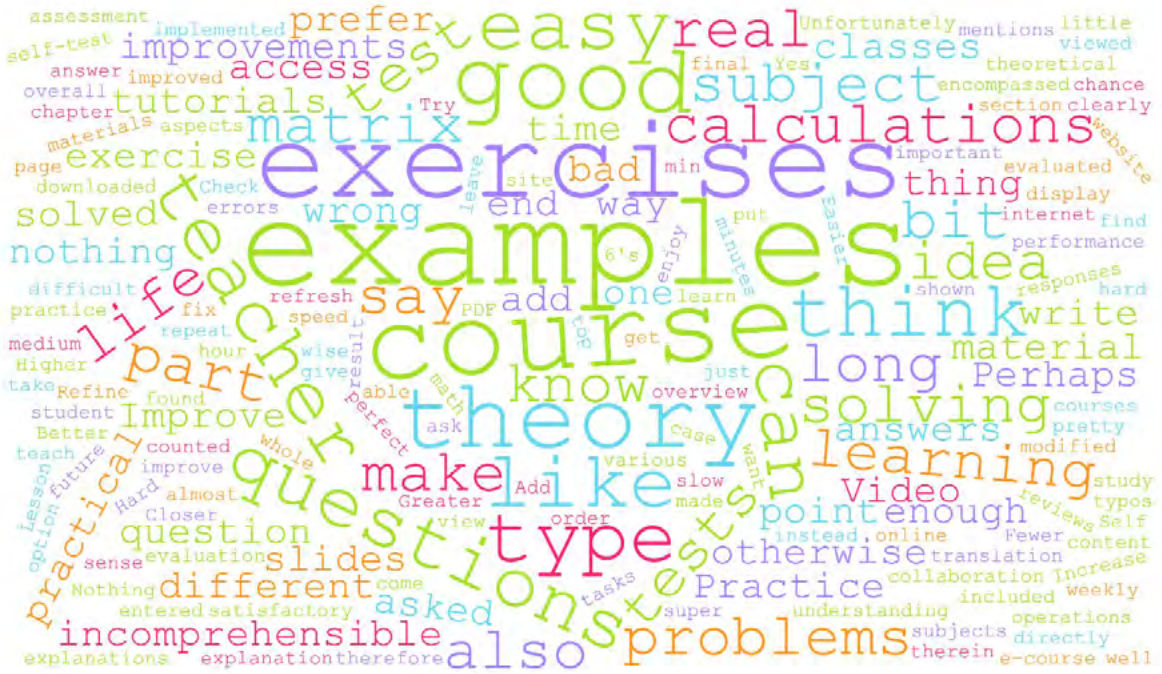

Fig. 1. The word cloud of terms used by students

Students were asked how the course can be improved. Most words showed appreciation for the material but they also indicated the desire for more exercises and examples. The word cloud of students' open answers is given in *Fig. (1)*.

3.2 Discussion

The present study aimed to present the preliminary results of a pilot study of an engineering mathematics online course. The most important results obtained showed that most of the students did not have any difficulties at all with the course material. The authors conclude that the chosen methodological solution and course design are functional. Most respondents considered that the course material will help them with the final exam which suggests good bonding between different parts of the materials.

However, the authors also found the parts that needed further development. The feeling towards the material's usefulness in practice was not as strong. To address this shortcoming, the Irish partner is already working on engineering tasks to link the content being learned to real life situations. The students also indicated the desire for more exercises and examples in learning materials. This shows that learners are supported when the content they learn is presented in an illustrative way and that they are guided to actively use the learning material.

Another important conclusion resulting from the pilot course is that the decision to run a pilot course has proved to be very important, as all the differences mentioned above between countries have surfaced in the development of this pilot course. This has allowed the consortium to take the appropriate decisions to solve the problems arising from these differences, and that, in the next academic year, the implementation of the online course will be as successful as possible.

4 SUMMARY AND ACKNOWLEDGMENTS

The study was conducted on a very diverse sample: students from six European countries with different ages and levels of experience. Still, the results of the pilot course suggest that the materials and tests of the engineering online course are of high quality and helpful and that students had a pleasant experience interacting with them. The theoretical materials had an appropriate amount of text and the students liked the graphics. There was more than enough time to solve assessment tests. The materials were perceived as being helpful for both their final exams and in real life even though the effect was more moderate in the later. Nevertheless, some lessons have been learned on how to better improve these materials for future courses. The students felt that more exercises and problems would improve the materials and they preferred to link the content being learned to real life situations. Results of described pilot study will be taken into account before conducting a final course. The same study will be conducted next year after the final course to get feedback on the changes made and confirmation of the results of the pilot course.
Students nowadays are leaning more and more towards practical applications in all fields, even in mathematics. Given the vast amount of information accessible to them, they need guidance in solving particular practical problems fast. The online medium is beneficial for the dissemination of information but user experience is very important to them.
A standard common course of engineering mathematics materials, assessment techniques, presentation and access are expected to impact the higher education community through facilitation and greater transferability of knowledge across the partner institutions. This approach will enable greater cooperation and understanding with similar institutions in European Union. The course structure and all supporting materials are being developed in different electronic platforms of each university for better access to the materials for students. This action ensures continued access after the project.

This work has been funded through the EU ERASMUS+ Programme – Strategic Partnerships (Key Action 2). All materials created during the project will be open to all on project website.

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WORKING-LIFE-INTEGRATED ENGINEERING CURRICULUM DESIGN AND ENHANCING THESIS PROCESS

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ABSTRACT

Working life, and the expertise it requires, is undergoing a rapid change. For this reason, it is particularly important for universities to focus on future working life skills and competences needed in a variety of work roles and working environments. The

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student's expertise in his / her field develops throughout the course of his / her studies. In both B.Sc. and M.Sc. thesis phase, a student should already be able to utilize and demonstrate the expertise to a certain extent.

This study presents a work-integrated curriculum model designed for engineering education. Within the identified drivers that guide the curriculum work in the technical fields, a model that considers the perspectives of corporate cooperation and business knowledge, was constructed and piloted. The model also provides a more flexible integration of future development trends into the education.

In order to make the thesis process more efficient, a virtual environment for the internship and thesis exchange was planned. It approaches the development of expertise in such a way that the university does not define the knowledge goals, but students are guided to do it themselves. This also includes interactivity: although the thesis always has certain limitations, it is not removed from its context and environment, but defines what is expected of the author. The platform has been piloted in the Mechanical Engineering bachelor's thesis process at the university, and the results will be discussed in this paper.

1 INTRODUCTION

The expertise needed in today's working life is different now than twenty years ago. Routine expertise, which works effectively in a familiar situation, is often no longer sufficient, but many tasks such as leadership, research, planning and combining these require adaptive and appropriate expertise. For this reason, it is particularly important that also universities as education providers will focus on the future skills, qualifications and competences in different jobs and environments.

The aspects of permanent needs to respond to the fast-changing demands of engineering education and to continuously develop its programs and improve curricula and teaching/learning arrangements have been highlighted especially in context of Bologna process for years. [1]. It has also been discussed how multi- and transdisciplinary teaching and research could possibly coexist in a meaningful way in today's university structures, and especially how these viewpoints could be integrated with sustainable development [2]. Some researches highlight needs and present recommendations for developing engineering education to increase students' "soft skills", e.g. personal achievement motivation, leadership potential, personal effectiveness and self-presentation [3]. Number of studies have also been done about entrepreneurship as one of the key expectations to engineers and their training. These efforts have been integrated e.g. with students' skills of business and society aspects. The effects on curricular design and academic reform have been discussed correspondingly [4].

After graduation, general working life skills such as teamwork, communication and problem solving expertise are essential in addition to the degree of substance expertise [5]. Both substance skills and general working life skills are part of the expertise required from graduates, which also includes some knowledge of companies

and practices in their own field. In a high level of expertise, theoretical, practical and experiential knowledge are strongly integrated, although in traditional teaching these have been treated separately [6].

The students' expertise in their field develops throughout studies, and in the final thesis they should already be able to apply and show expertise to a certain extent. Unfortunately nowadays, students are generally not well shaped by technological experience due to tightening graduation deadlines. In order to support the development of professional expertise besides substance education, it has to be taken into account already in curriculum development work. Also, it is important that students have a realistic understanding on their expertise, and what is expected of them in working life.

This article presents a model of curricula integrated into the world of work, and a related, guided thesis process which were implemented in a mechanical engineering degree programme. The guided thesis process was piloted in spring semester 2020, and the gained results from this pilot are also discussed here.

2 METHODS

2.1 Working-life integrated curriculum design

A curriculum refers to an action plan that guides education and learning, the development of which aims at high-quality student learning. From the student's point of view, the curriculum is either a study guide or a personal study plan, and for the teacher it provides an aid for locating and implementing his/her own teaching. At university level, curricula consist of educational programmes or comparable educational products, illustrating the expertise of the discipline and the relationship with other disciplines and society [7]. In addition, there is are some political regulations of the national education system concerning curricula in education organisations [8].

When designing a model of curriculum work integrated into working life, drivers guiding curriculum work in the field of technology were identified in the first phase. These strongly contributing factors include several educational policy objectives, which are set both from outside and inside of the university. In addition, in educational products, such as master's programmes, there are requirements which are imposed both for the development of the content, and implementation of teaching methods. Development in discipline, as well as in companies and working life, set their own requirements in curriculum design, and some drivers may originate also in an individual level.

Universities are subject to external guidance, which will be influenced by the guidelines drawn by, e.g., the Ministry of Education and Culture. The time targets for graduation and the cost-effectiveness of teaching activities, profiling and possible regional policy solutions, are examples of these principles. Through the university's internal guidance, curriculum work is guided by various strategies, such as concern strategy, internationalisation and digital strategy and the strategy of an entrepreneurial university. One of the drivers from within the university, is the educational-product thinking, which builds study modules for different target groups, such as international

master's programmes or education programmes for life-long learning. The design and development of teaching content also depends on, for example, identified or predicted future trends, the emphasis on multidisciplinarity and the skills required of graduate students. When choosing a method of education implementation, at least the following factors have to be taken into account: available financial, time and labour resources, possible business cooperation, target groups for education and flexibility.

The forces driving the design of educational products are shown in Fig.1.

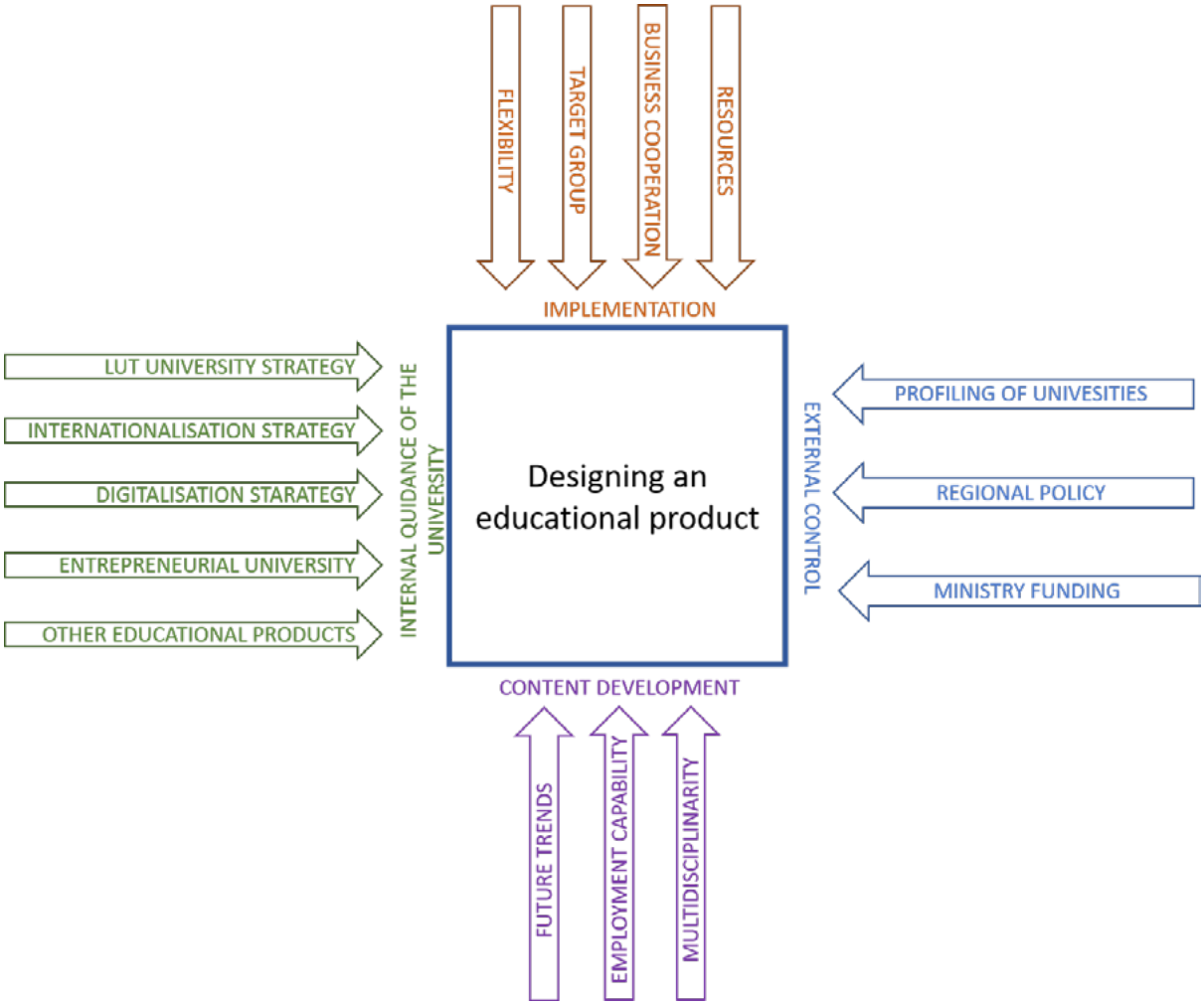

Fig. 1. Drivers for the content and development of educational products.

Based on Fig. 1, it was possible to build and pilot a curriculum work model that takes into account the perspectives originating from business cooperation and the skill needs of companies more clearly and faster than before. The model summarises the curriculum process by increasing the teaching of research-based work before starting the thesis and, on the other hand, preparing a working-life oriented way together with the thesis sponsor [9]. The model consists of basic studies in research methodology, laboratory work course in the corporate environment, and subsequent thesis. The implementations are not separate courses, but support the thesis, as shown in Fig. 2.

The main part of the curriculum work is the laboratory work course, the scope of which is 2-30 credits, depending on the company-oriented project. This flexibility makes it possible to use the course in both bachelor's and master's stages. The course develops student's capacity to use research approach and solve the real problems identified by the companies. At the same time, it provides the basis for longer-term business cooperation and allows the preparation and start of the thesis. The course will be carried out as a project that is planned together with the company, the student and the supervisor from the university. A project plan, follow-up reports and a final report are prepared for the project, reflecting the implementation of the plan.

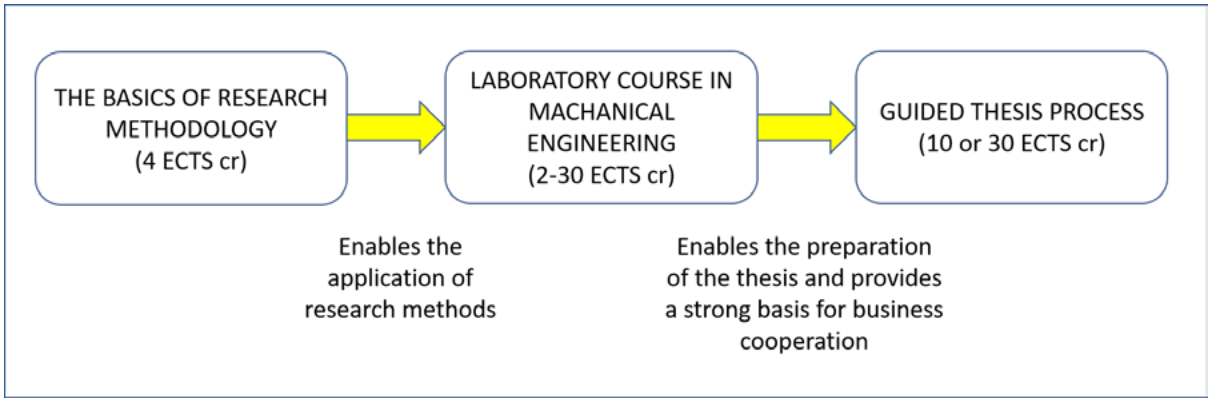

Fig. 2. As part of the curriculum work process that is integrated into working life, the thesis implementation model is used to support the advancement of both international and domestic students. The core of the process lies on three integrated courses.

When analyzing the effects of content and development drivers (Fig.1) on the implementation model (Fig.2), the most strongly influencing driver in practical development work has been the flexible digital implementation of course modules due to the modern requirements of distance learning possibilities. However, from the content point of view, the profiling based on the university's own strategic strengths is the most important factor. Nowadays, the course materials are developed for international students and the most used language is English. Behind these almost self-evident aspects there are number of connections between the drivers and the model. Firstly, the content of research methods course module is required to give basis for the scientific approaches needed in the *Laboratory work course* and further during the thesis project. The content should be discussed personally with each student and with the company in which the exercise work will be completed. Secondly, it is important to notice that the total amount of credits of the *Laboratory work course* can be established to be between 2-30 credits which gives students some freedom to select either only this course module in its entire broadness or keep the amount of credits a bit limited and select e.g. some business-oriented studies instead. This flexibility of credits makes it possible to take into account the driving forces of business cooperation, regional policy and entrepreneurship. These aspect are to ensure

students' better employment capabilities at the specific company in which he/she has worked during his/her laboratory work course already before the final thesis will be completed. Thirdly, during the *Laboratory work course* it is also possible to give the company the possibility to get familiar with university's expertise (profile) and take advantage from university's knowledge before the thesis project. Both sides can learn from each other and the co-operation between the student, the company and the university has a longer perspective.

2.2 Improving the efficiency of the thesis process

At the end of the studies, it is important to support the smooth running of the thesis process. To this end, the evaluation criteria for a thesis in working life cooperation were clarified and the Stock market of internship and master thesis positions, aimed at improving the thesis process, was built and piloted. Stock market here refers to a platform where students and organizations may find each other, i.e., it does not mean an ongoing trading of these positions.

One of the aspects increasing the novelty value of the process is the way to increase the time period in which the student, the company and the university follow the common path of studies. It is also important to notice that even though the company and the university are involved more to the process, the individual choice of the research topic and thesis topic are still offered to the student himself/herself. Of course, the strategic goals of the university and the values set by the company are building the framework for student's choice but to keep students motivated some freedom is left to them.

It has been shown that different computer and distance learning assisted ways, e.g. MOOC [10] or augmented reality applications [11], can increase students' motivation. Together with them the given freedom to students can give promising results in learning. Our model is supported with the driving force of digitalization, which means in this case, that we apply Moodle environment in each of the courses included to our model. There is evidence available that this kind of assisted freedom of choice really supports students' motivation [12].

It is also noticeable that scientific aspects are combined with practical aspects together with company and university sides. In many cases, these aspects are regarded as separate ones, thus the importance of integration is known in many universities around the world. One minor thing is that in this model, it is possible to tune the amount of obligatory engineering studies if needed.

2.2.1 Evaluation of the thesis in working life cooperation

The thesis in the field of technology usually involves a student, a university supervisor and a company that offers the subject of the work. Often, a company representative is also acting as a second supervisor of the work. The company evaluates the student's skills and expertise with its own criteria, which often include 21st century skills, such

as sensemaking, social intelligence, applied mindset, and the ability to operate in a multidisciplinary and multicultural environment.

The University, on the other hand, uses other criteria for evaluating the thesis, which make it difficult to directly assess the expertise. The students' own perceptions of their skills and the development of expertise are reflected in e.g. some questionnaires by a trade union, which offer different options for expressing competence. These above-mentioned criteria are all different.

In theses projects involving both the student, the company and the university, it is crucial that all parties agree what kind of outcome is sought. Otherwise, one of the possible stumbling blocks may be if practicality and research are seen differently in the university and company. It can also be difficult for students to understand the difference between a practical problem and research questions. Unfortunately, guite often the research issues in students' final theses are addressed by a practical problem, and for example, a question beginning with '*Why*' may be not presented and answered. This usually means that the applicability of the results is limited only to applications analogous to the situation studied.

In a working-life oriented thesis, it is also important to define already at the beginning how to work together [13]. A starting meeting can be held between the student, the supervisor and the company, so that they can agree on guidance, schedule, possible costs and inventions, objectives and evaluation of the finished work. A common evaluation rubric which is tailored at the beginning to suit the specific work, can be a great help in evaluating the thesis. A good thesis produces new information for both the company and the scientific community through the identified research methods.

2.2.2. Stock market of internship and final thesis positions

In order to improve the efficiency of the thesis process, the development of expertise is approached on the *Internship and thesis stock market* planned for mechanical engineering degree programme. Here, the university does not define competence objectives, but the students are directed to do it themselves by familiarising with their target company and subcontracting networks, and by identifying what skills are needed in this workplace. This also includes interactivity: although the thesis always includes certain boundaries, it is not removed from its environment, but can be used to determine what is expected of the author. It is important that students are able to show their own activity in forming the required contacts with companies and possible supervisors, see Fig.3.

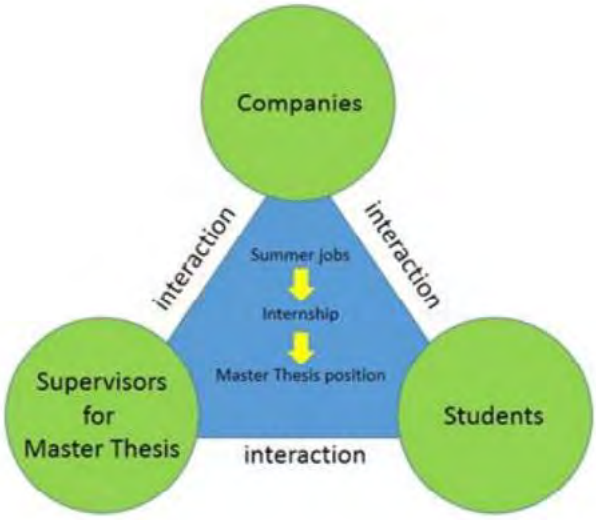

Figure 3. The role of student's own activity in finding the internship and final thesis position.

Today, there is an increasing effort to ensure that studies are time-independent and independent of education. Accordingly, the development environment for theses was also built on an online platform.

Traditionally, both the student's and the supervisor's knowledge background is reflected in the thesis. In addition, when a representative from a company is also taken into account, the required expertise will be raised even more. At best, when these different types of expertise meet, high-quality and creative solutions are achieved. According to Talikka [14], it is easier to handle expert interfaces in an objective environment where information encounter, and it is not so much individuals. Thus, the development environment for theses may serve as an excellent meeting place for these different expertise.

The Moodle implementation of the stock market was built on the schedule frame shown in Fig. 4, which is applicable to the control of both bachelor's and master's thesis. In B.Sc. thesis, the time from beginning to end is 4 months, and in M.Sc. thesis 6 months. The implementation consists of 6 different sections: *Abstract and introduction, Literature review, Research methods, Result, Discussion* and *Summary*, which all include pertinent lectures and exercises. In the schedule, the description of the research problem, the method description and the reflection section receive especially much guidance since before, they have been found to be difficult for students to internalise. In addition to lessons and learning tasks, the implementation schedule includes several hours of individual student guidance and on the other hand, presentation of the progress of the work to other students. These check points are marked with an '*x*' in Fig. 4. This way, students' theses, and their methodical choices can benefit collectively the entire group of participants. All supervisors who had their students in the process were also be kept informed of the ongoing thesis topics and their progress.

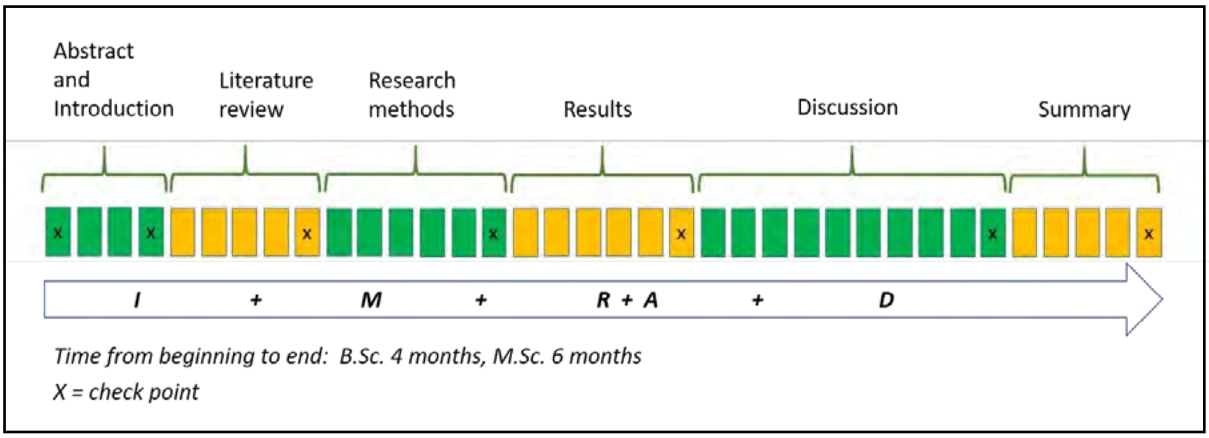

Fig. 4. The schedule frame created as the basis for the supervision of the thesis.

When students understand their future operating environment, the desired expertise is created. The most important expertise that is needed for the work is the deep understanding of substance, although general capabilities are also important. *The Stock market of internship and final thesis positions* site can guide students in this. In the *Subcontracting Networks* section, students are instructed to ask questions about expertise and find answers to them. The students can also get help in making a job application from the thesis exchange, which often asks you to describe their skills. These cannot be pre-given, but the student must find and dictate them himself.

The virtual implementation of the internship and thesis exchange takes into account the international nature of the students: the site is made in four languages: Finnish, English, Russian and French. In this way, international thesis workers are offered the opportunity to practice their skills and to become better equipped in Finnish working life.

The guided thesis process is of paramount importance in the bachelor's phase, but also useful in the master's degree, especially in the field of research methodology and project work skills. The department of mechanical engineering has tested three different ways of completing the studies on the *Basics of research methodology (4 cr):* either entirely as distance studies, traditional literature or intensive courses. Out of these, intensive course has proven to be the most effective. The guided thesis process also includes a specified guidance on information retrieval of the thesis, which is held by the information specialists of the Science Library. In addition, information retrieval workshops are carried out as part of the guidance of bachelor's work. The material is also suitable for distance learning.

3 RESULTS

The curriculum model together with the scheduled, guided thesis process has been piloted in the university with mechanical engineering students working on their B.Sc. thesis during spring semester 2020. The results from the pilot showed that the new model has been quite effective. About 60% of students who started their thesis in

January were able to complete it until May. It is also expected that about 20% more of them will complete their work until the end of July since supervisors were able to contact 80% of candidates during the last weeks of semester. Only some students dropped out from the course. The final number of participating students was 40. Table 1 summarises the main findings and future progressions in the curriculum work model.

Table 1. Experiences from piloting the curriculum model in the academic year 2019-2020.

Curriculum work model integrated into working life, pilot 2019-2020		
Tool	**Findings**	**Next steps**
Exploitation of content and development drivers of educational products	The most strongly influencing driver is the educational product. The *flexible digital implementation* is highlighted. In content, the *profiling* based on the university's own strategic strengths is the most important factor.	Increasing business cooperation by taking advantage of the marketing opportunities created by different educational products.
Utilising the combination of research methodology, laboratory work course and thesis	From the point of view of business cooperation, the laboratory course has proven to be particularly successful.	Improve the implementation by grouping, based on selected project work topics.
Utilizing the Stock market of internship and master thesis positions	45 students enrolled in the pilot course in Moodle environment. However, all possibilities in the environment have not been utilized at all.	Integration of the Moodle environment into a research methodology course or other professional subject in the next curriculum work round.
Take advantage of a scheduled guided thesis process	42 students started in the pilot phase, (target to be completed May-June/2020).	Highlighting that the Moodle package will be implemented twice during an academic year. About 1/3 of those who were now enrolled had come too early.

A clear majority of students who gave feedback (n=20) about the guided thesis process pilot, were satisfied with the amount and content of both lectures and learning tasks. Supervisor meetings that were part of the process, received particular praise. Up to 90% of respondents thought the number of teacher meetings was appropriate, and the remaining 10% would have liked even more of them. All respondents told that the meetings helped to make a lot of progress on B.Sc. thesis work. A guidance organised by the library was also found useful by 95% of respondents. A technical implementation of the course site was also considered good by 85% of respondents.

A few critical comments were given about the course schedule in relation to bachelor's work. Also, different kind of B.Sc. theses could have been better taken into account; some of them are more theoretical and some include more empirical work for example

in laboratories. Fig. 5. shows that students wanted to add writing workshops and meetings with supervisors in the process. Lecture videos were also mentioned besides lectures, which might reflect the influence of COVID-19 pandemic during spring 2020.

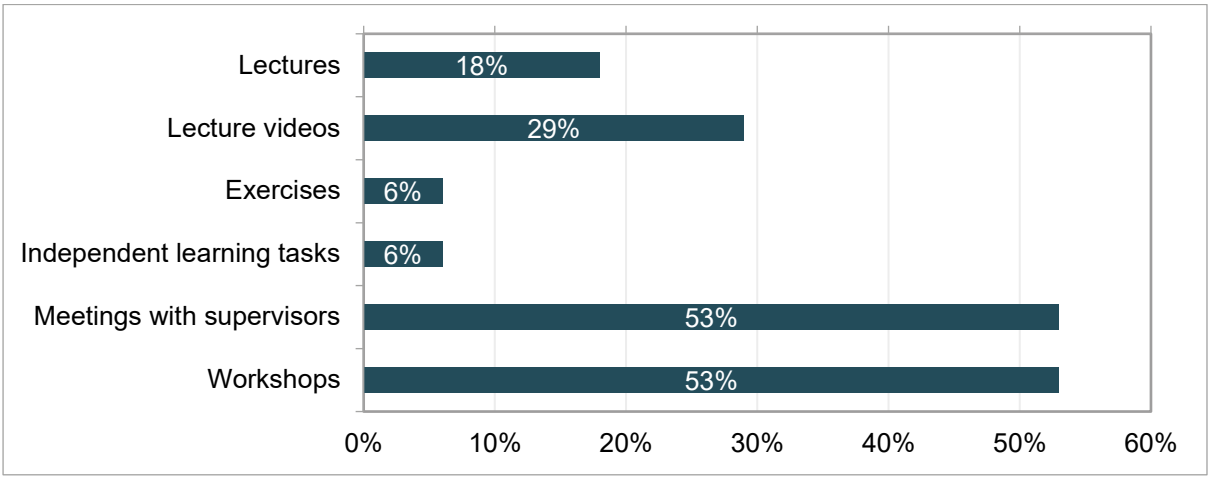

Fig. 5. Feedback: what students said they want to add in the guided thesis process.

In general, students believed that the guided thesis process contributed to the completion of the work, and most of them thought that the impact was high.

Teachers' feedback was also positive. Especially, supervisors felt that they can concentrate better on the substance in the meetings, since they do not have to go through e.g. the IMRAD structure separately with every student. They also said that the students are now much more active in the meetings. The overall progress of bachelor workers seems to be more even, too:

> *"A few students had difficulties in achieving/following the bachelor's course schedules for the results. In any case, few slower ones would have stretched over the summer in previous years, but now they are also trying to finish the work in this spring. It's a very good improvement over previous years."*
> - *A supervisor*

Based on supervisors' feedback, it also appears that, besides the formulation of the report, the new model gives students more thought about the role of research questions, ensuring the reliability of the results and other issues relevant to the scientific level of the thesis.

The results of this study seem to imply that, even though uncovering the curriculum design to the outside expectations increases the number of potential variations in the flow of studies, the process pays off in form of increased study motivation and outcome regarding especially the demands of thesis and modern work life. Additionally, it seems that this approach is an iterative process, for years to come. Challenging yes, but it may also provide a new insight into the quality of universities' educational processes. The shared path between a university, an industrial partner and a student

begins from the bachelor level studies providing a strong impulse and solid foundation for the last standing and productive co-operation in the future.

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SURVEY ON ENGINEERING ETHICS

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ABSTRACT

The raise of artificial intelligence applications has awoken growing interest in ethical issues relating to engineering. However, this AI-focused trend does not address ethical issues that are present in traditional engineering work. Further, many publications discuss the ethics of technology from outsiders' point of view, not as the ethics of professionals in engineering. In this paper, we describe ongoing research on engineering ethics from the engineers' point of view.

The main objective of the study is to identify ethical problems that engineers of different disciplines encounter in their everyday work. Results will be used to formulate the contents of ethical studies for engineering education, with the final goal of suggesting how ethical contents can be embedded in engineering education.

Secondary usage for the results is to suggest how the Association of Academic Engineers and Architects in Finland should support its members with their real-world ethical questions.

The goal of this paper is to describe the questionnaire designed for the purposes above and invite fellow researchers to conduct similar surveys outside Finland.

Conference Key areas: Sustainability and ethics. Engineering curriculum design.

Keywords: engineering ethics

1 INTRODUCTION

Engineers work with many of the core functionalities that shape our society. In some fields, such as artificial intelligence, the importance of ethical issues has been recognized as something affecting the engineering work and high profile issues are also publicly discussed. However, such discussion does not address ethical issues that are present in more traditional engineering work [1]. There exist several ethical codes for engineers like the Archimedean Oath [2] or the codes of IEEE [3] and ACM [4]. These codes describe the ethics but do not help engineers when an active ethical issue is at hand.

The questionnaire described in this paper aims to better understanding of what kind of ethical issues engineers encounter during their professional life and how the ethical issues are handled in the workplaces. Understanding the nature of ethical issues can then be used to design

how ethical contents can be embedded in engineering education in such ways that it supports the professional life of the future engineers. The results are used to help the Association of Academic Engineers and Architects in Finland (TEK) to offer support for its members with real-world ethical questions and problems. The survey described here will be conducted for about 5000 members TEK during 2020.

The structure of the paper follows the structure of the survey. The questionnaire is composed of two main sections:

- A common part for all respondents about ethical attitudes the engineers have, general demographic questions, ethical support and ethics in education. These questions are discussed in Section 2.
- Secondly, a case section, where respondents can describe ethical issue or issues they have encountered in their professional life. The case specific section is given to respondents who indicate that they want to describe encountered ethical issue in more detail. These questions are introduced in Section 3.

The reason having separate part of cases is to encourage respondents who have not encountered specific ethical issues to answer the questionnaire.

2 THE COMMON PART OF THE QUESTIONNAIRE

The common part of the survey consists of three sections: about the general ethical attitudes of the engineers, background information about the respondents, and post questions about ethical issues present in respondents' studies and what kind of support the respondents' would like to have in ethics issues.

The first and second part of common questions form the first part in the whole survey, then follows the case part described in Section 3, and the last part is the post questions of the common questions.

2.1 Ethical attitudes

The survey begins with questions about the general ethical attitudes of engineers. To measure engineers' sensitivity to ethical issues, a selected group of questions was taken from the ethical sensitivity scale by K. Tirri and P. Nokelainen [5]. Original scale included 28 questions divided into seven categories. To reduce the total length of the survey, only 14 questions were selected. The selected questions included all questions from categories "Preventing social bias", "Generating interpretations and options", and "Identifying the consequences of actions and options". In addition, two questions were selected from category "Working with interpersonal and group differences" as they focused on identifying or reacting to ethical issues. The selected questions are presented in Table 1 with original identifiers from [5]. Question es7_27 is modified to use term "work" instead of "school". The ethical questions are collected into Table 1. All ethical sensitivity scale questions should be answered with a five-point Likert scale, where one is "totally disagree" and five "totally agree" [5].

Table 1: Selected ethical sensitivity scale questions [5].

Identifier	Question
es4_15	When I am working on ethical problems, I consider the impact of my decisions on other people.
es4_16	I try to consider other peoples' needs, even in situations concerning my own benefits.

Continued on next page

Table 1 – continued from previous page

Question	Options
es5_17	I recognize my own bias when I take a stand on ethical issues.
es5_18	I realize that I am tied to certain prejudices when I assess ethical issues.
es5_19	I try to control my own prejudices when making ethical evaluations.
es5_20	When I am resolving ethical problems, I try to take a position evolving out of my own social status.
es6_21	I contemplate on the consequences of my actions when making ethical decisions.
es6_22	I ponder on different alternatives when aiming at the best possible solution to an ethically problematic situation.
es6_23	I am able to create many alternative ways to act when I face ethical problems in my life.
es6_24	I believe there are several right solutions to ethical problems.
es7_25	I notice that there are ethical issues involved in human interaction.
es7_26	I see a lot of ethical problems around me.
es7_27*	I am aware of the ethical issues I face at work.
es7_28	I am better than other people in recognizing new and current ethical problems.

2.2 Background questions

The demographic question section includes the personal questions about birth year, the year of Master's degree or equivalent, the alma mater, the degree programme for Master's degree, gender, and position in current workplace. In addition, there are questions related to the respondent's current or the most recent workplace, that are presented in Table 2.

Table 2: Workplace-related background questions.

Question	Options	
B1: How many people currently work at your workplace, or your most recent workplace?	1 – 5 21 – 50 251 – 1000	6 – 20 51 – 250 over 1000
B2: Does your current or most recent workplace have official procedure to bring forth ethical issues or problems? Select all applicable.	No Yes, designated contact person Yes, anonymous channel Do not know	Yes, ethics committee Yes, through regular chain of superiors Yes, other; please specify.
B3: Does your current or most recent workplace have official procedure to address and solve ethical problems or to their after-care? Select all applicable.	No Yes, democratic processes of employer and employees. Yes, superior Yes, other; please specify.	Yes, committee or named group who gives statement Yes, peer support between coworkers Yes, support person Do not know

2.3 Post questions

All respondents are asked three post questions to map the general status of ethical issues in engineering work and studies. The first question P1 is about the need for support in ethical questions. Its answers are collected with the matrix which is used in questions S25 and T25 of case studies, too. Respondents select the desired types of support with the wanted providers. Options for both types of support and providers of support are presented in Table 3.

Table 3: Matrix headers for questions P1, S25 and T25

Providers of support	Types of support
Company or organization itself	Support personnel during decision making Ethical board or committee
Provided by the company or organization but produced by external actor such as consultant or occupational health care	Educational material such as example cases and their solutions Educational material such as ethical codes Organized peer support
Labor union	Legal services
Self provided	Support personnel for after care
Other, what?	Other, what?

Our hypothesis is that ethical questions are not clearly present in engineering studies. Question P2 is about the state of ethical issues in respondent's studies and P3 is asking respondent's opinion about how to discuss ethical issues in studies. Answers to these questions are used as a basis when making a suggestion how to take ethics into account in engineering education. The post questions are presented in Table 4.

Table 4: Post questions

Question	Options
P1: What kind of support you think is needed in general?	The matrix of Table 3.
P2: Were ethical questions or issues discussed during your studies?	Separately as ethical issues or on a dedicated course Combined with other topics. Not discussed at all.
P3: How you would have liked ethical questions or issues discussed during studies?	Open answer.

3 THE CASE PART OF THE QUESTIONNAIRE

The case specific section contains questions about ethical issues the respondent has encountered during their professional life. The respondent can select between "single case" or "type example", or both. The respondent can describe several cases of both types. Here the "single case" refers to a situation where the respondent wants to describe a specific incident or ethical issue they have encountered. "Type example" can be used when the respondent has encountered similar ethical issue multiple times during their professional life, either within one organization or at different organizations. The selected type affects some of the questions.

This section describes the case specific questions. Questions are divided into four categories: The time frame of the issue, the field, type and description of the issue, the issue detection, and the issue solving process. Questions posed in each category are described in corresponding sections. Each section describes both single case and type example questions.

Some ethical issues can be prevalent and are encountered multiple times by engineers during their professional life. Separation of type examples from single cases allows to more easily identify what are the common types of ethical issues an engineer can encounter. In addition, it should make the answering easier for the respondent. As the single case and the type

example share many of the questions, both cases are discussed in this section.

Questions are given ID starting with S for single cases and T for type examples. As question sets for these categories share many questions that are exactly the same or very similar, the equivalent questions will share the same numbering for both the single case and the type examples. As there are also questions that apply only for single cases or type examples, there are missing numbers in both set of questions.

3.1 The time frame of the issue

To determine if the encountered single case issues are recent or old, and if they were short-lived situations or continued for prolonged time, questions described in Table 5 are asked from respondents. The age of the problem is used to see if the nature of problems has changed over the time. The duration is used to find out how long the situation was accepted.

With type examples, the respondent might have encountered the issue multiple times in different organizations over the years, so type example does not have equivalent questions for S1 and S2. However, it does have type example unique question T3 to help to evaluate, how prevalent the issues are and if it is common for engineers to encounter similar problems during their professional life. Understanding what the commonly encountered issues are, allows targeting education and support for those kinds of cases.

Table 5: Questions on the issue time frame category.

Question	Options	
S1: How long ago the case happened / started?	0 – 5 years ago Over 10 years ago	5 – 10 years ago
S2: How long the ethically questionable situation continued?	Days Months Do not know	Weeks Years
T3: How often you have encountered ethical issue of this kind?	Couple of times Often Habitually, or it is the prevalent way of acting.	Once in a while Do not know or prefer not to answer

3.2 The field, type and description of the issue

The issue field and type category in Table 6 includes questions S/T4-S/T7 about the nature of the ethical issue and field it was encountered in. The purpose is to recognize the area of engineering in question. As the problem can arise from application area, which is expected to often happen e.g. in information technology, this information is also collected.

With the type example, it is also important to distinct whether the issue was encountered multiple times in the same organization as that allows organization to change their policies, or if it was in different organizations. Further, separating these two allows us to understand if the issue is an indicator of single organization having problems, or if the ethical issue is prevalent in the industry. For this purpose, question T8 was added for the type examples only.

Last two questions ask for the description of the issue itself and its working environment. Last question for the type example allows several alternatives to be answered.

Table 6: Questions on the issue field and type category.

Question	Options
S4, T4: Was the ethical issue related to (select all applicable)	Working terms, conditions, management or human resources (General workplace ethics, GWE) Behavior or attitudes at workplace (GWE) Job applying situations, hiring (GWE) Contracts (Professional ethics, PE) Conflicts of interest, positions of trust (GWE) Specific product, its operation or features (PE) Work processes (PE) Marketing, competitive tendering, customer acquisition (PE) Engineering work and its core questions or consequences (PE) Other, please specify.
S5, T5: What kind of potential or actualized negative consequences this ethical issue / problem caused or could have caused? (Select all applicable)	Life, health or safety related Decrease in well-being, discomfort Regarding equal or fair treatment of humans Financial consequences, either for company or organization, its customers or society as whole Environment or nature related Confidentiality or (human) privacy related Customer or client could not get product or service they purchased/contracted Deception, manipulation or exploitation Endangering person's autonomy or their possibility to do their own choices Breaking decrees or laws Other, please specify,
S6, T6: What field/line of work you were representing?	Options for this question should include country appropriate technical domains listed.
S7, T7: Describe the field or context of the ethical issue itself, if it differs from the previous question.	Open question
T8: Have you encountered issue of this type in multiple organizations or mainly multiple times within same organization?	In one organization In multiple organizations
S9, T9: Describe in more detail what kind of situation was and what happened.	Open question
S10: What kind of working/professional environment the ethical problem was present? Choose the most fitting option. T10: What kind of working/professional environment the ethical problem was present? Choose all options that fit.	Project in or with private company Production Consulting Teaching or research Public organization (government, municipalities, church, societies) Other, please specify.

3.3 The issue detection

For understanding the emotional condition of the engineer, it is important to know when the ethical issue was first recognized. It is also very interesting to find out, who noticed the ethical problem and how it was brought forward. People might be afraid of raising ethical issues into discussion, hence information on possible attitude changes to the whistle-blower is a relevant thing to gather. The questions related to the detection of the issue are listed in Table 7.

For understanding if and how organizations and individuals learn from previously encountered ethical issues, there are some questions specific for type examples added (T12, T14, T17) or altered (S11, S13, S16) to identify, how the behaviors change when encountering the subsequent cases of the issue type. This can open up possibilities to explore, if education could pre-emptively help the individuals and organizations to build processes to handle ethical issues. It is also possible that instead of learning, desensitization or frustration rises, which is why change in attitude changes is collected.

Table 7: Questions in Issue detection category

Question	Options
S11: When the ethical issue was noticed or when you yourself recognized it? Choose most fitting option. T11: When the ethical issue was noticed or when you yourself recognized it for the first time? Choose most fitting option.	Before starting or committing to operation (for example: before signing contract, before starting internal project, ...) During planning or specifying the operation In the middle of implementing After completion but before deployment During deployment or shortly after Later / Afterwards Do not know
T12: Was the issue noticed, or did you notice the issue earlier or faster on the subsequent times the issue was encountered?	Yes, always Yes, most of the times No Do not know
S13: Who noticed the ethical issue? T13: Who noticed the ethical issue for the first time?	You yourself Member of work community / someone working with the project Other stakeholder in the project External actor or public officer Other, please specify. Do not know or prefer not to answer
T14: Who typically noticed the issue on the subsequent times this kind of issue was encountered? Select all applicable.	Same as above You yourself Member of work community / someone working with the project Other stakeholder in the project External actor or public officer Other, please specify. Do not know or prefer not to answer

Continued on next page

Table 7 – continued from previous page

Question	Options
S15: How the ethical issue was brought forth? Select all applicable.	It was not brought forth at all During private conversations with colleagues During private conversations with responsible person In project meeting / similar session Through official channels Anonymously (for example suggestion box or other anonymous means) Other, please specify.
S16: How did the attitudes of the work community or employer change for the person/persons who brought forth the ethical issue? T16: How did the attitudes of the work community or employer change for the person/persons who brought forth the ethical issue for the first time?	To very negative, possibly also concrete consequences such as firing the person/persons To negative, but mostly social consequences such as resentment or disapproval Attitudes did not change (neither to positive nor to negative) To positive, but mostly social consequences such as respect or gratitude To very positive, possibly also concrete consequences such as rewards Incoherent attitude changes: some attitudes changed towards positive, some towards negative None of the above / Do not know Issue was not brought forth, so no changes.
T17: How did the attitude changes on subsequent times compared to the first encounter?	Change was more positive Did not change in substantial manner Change was more negative Do not know

3.4 The issue solving process

It is important to find out the reaction of the decision makers to the problem and how they decide to handle it. It is also worthwhile to see if the decision was in line with the organizations policy and the culture. Since many engineers are themselves decision makers, this information is also collected. There might be bias in answers that show ethically positive reaction if the respondent was making the decision themselves.

The available and wanted support are asked to see their need in engineers' work. The support wanted and the potential provider of the support are asked using the matrix introduced in Table 3. These questions are important for our research partner, TEK.

As with the issue detection for the type example, it is important to understand, if previously encountered issues cause lasting effects on the organization's or individual's capabilities to handle similar ethical issues. In cases where the issue was encountered in different organizations, it is impossible to determine if organizations have revised their processes. However, it allows exploring, if organizations differ in their behavior when they encounter similar problems. To gather information about these, there are several varied or type-example-only questions. The last question asks for permission to use the case description in educational material if it is made anonymous and sanitized. All questions on this category are gathered to Table 8.

Table 8: Questions in Issue solving process category.

Question	Options
S18: What was the reaction of the decision makers to solve or handle the ethical issue / problem? Select all applicable. T18: What was the reaction of the decision makers to solve or handle the ethical issue / problem for the first time? Select all applicable.	Negative reaction towards bringing it forth Issue was ignored or buried Issue was discussed on but actions were not taken or the issue was left to hang in the air Policies or practices were changed It was decided to withdraw from the situation or project, or refused to join or participate in it Do not know or prefer not to answer Issue was not brought forth, so it was not handled.
T19a in one organization: Did the organization's reaction change on subsequent times?	Did not change. Did change, how? Do not know or prefer not to answer.
T19b in multiple organizations: Did the reactions between different organization differ from each other?	Not substantially. Yes, how? Do not know or prefer not to answer.
S20: How was the decision made? T20: How was the decision made for the first time?	Person(s) responsible made the decision Consensus was reached or vote was taken There was not clear decision Issue was not addressed at all Do not know or prefer not to answer
T21a in one organization: Did the decision making process change during the subsequent times?	Did not change. Did change, how? Do not know or prefer not to answer.
T21b in different organizations: Did the decision making process differ between organizations?	Not substantially. Yes, how? Do not know or prefer not to answer.
S22: Was the reaction to the ethical issue in line with the organization's normal culture or did it differ from it?	Yes No Do not know or prefer not to answer
S23: Were you the decision maker or person responsible during the ethical issue case? T23: Were you usually the decision maker or person responsible during the ethical issue case?	Yes, alone Yes, as a part of a group No Do not know or prefer not to answer
S24, T24: What kind of support was available in solving the ethical problem or issue? Select all applicable.	None Support types from Table 3 Do not know or prefer not to answer
S25, T25: What kind of support you would have wanted?	The matrix of Table 3.

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Table 8 – continued from previous page

Question	Options
S26, T26: Have you done any personal decisions or changes because of this event? Select all applicable.	No Switched workplace or resigned Switched department inside organization Took legal actions or filed police report Complained to administrative agency Contacted media Changed your own practices Prefer not to answer
S27, T27: If the case description is made anonymous and sanitized, can it be used as an example in ethical material?	Yes No

4 DISCUSSION

This questionnaire was to be sent to about 5000 engineers in Finland during April 2020. Unfortunately, due to the coronavirus pandemic, the actual implementation of the questionnaire is rescheduled to August.

However, one motivation for the early publishing of the questionnaire is to call for other researchers to do the same or at least close enough research in their area to get better understanding if the problems encountered differ in other countries or areas either in Europe or worldwide.

At this stage, we feel the survey will give answers to the following main questions:

- what kind of ethical issues engineers have encountered
- how the employer and the working environment reacted to the person raising the issue
- how the decision maker reacted to the issue itself
- if there are any systemic processes to handle the cases
- are the typical cases single occasions or way to behave
- what kind of ethical support engineers would like to have?

The results of the questionnaire are used as a basis for future work in finding the suitable topics and ways to include ethical issues in engineering education. Firstly, it is important to distinguish if engineers do not recognize ethical issues, if they do not know how to resolve the issues or do not see the issues worthwhile to resolve, or if the working environment is resisting. Each one of these require a different set of skills from the engineers. The nature the core issues can affect the way it should be approached during education: through separate courses, integrating teaching into existing courses or project works or as a part of the thesis. There might be problems of a different kind, depending on the engineering areas: we expect the problems e.g. in civil engineering, process industry, and information technology have different emphasis. The value of real life examples is also expected to be higher for educational material, compared with invented examples.

The other usage is for TEK. Their interest is to see the ethical problems faced in everyday engineering work, and how the association can support its members in these cases.

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THEATRICAL TECHNOLOGY ASSESSMENT: A ROLE-PLAY SIMULATION FOR TRANSDISCIPLINARY ENGINEERING EDUCATION

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Conference Key Areas: *Interdisciplinary education, Sustainability and ethics*
Keywords: *Role-play simulation, Transdisciplinary engineering education, Technology assessment, Responsible innovation, Emerging technologies.*

ABSTRACT

To be able to contribute to societal challenges, engineering students need to learn how to interact with societal stakeholders and incorporate their viewpoints in technology development. This proves to be difficult, especially when it concerns newly emerging technologies, which are characterized by uncertainty and ambiguity. This paper presents a novel educational method – Theatrical Technology Assessment – which combines insights from Constructive Technology Assessment and improvisational theater in a role-play simulation that enables engineering students to explore the socio-technical dynamics and alternative futures of emerging technologies. This method is tested with bachelor students at the University of Twente. Students were involved as players of the role-play simulation, but also as co-designers and role-instructors. The pilot study corroborates that a role-play simulation is a powerful means for students to learn about the complexity of societal interactions around emerging technologies. They learn about differences in stakeholder perspectives and ways to anticipate or transcend these, and about general patterns in socio-technical dynamics.

1 INTRODUCTION

To cope with societal challenges, such as the transition to cleaner energy production, engineers need to collaborate across disciplinary and societal boundaries. Yet, this transdisciplinary collaboration is challenging [1], due to the often mono-disciplinary education of engineers [2] and the differences in interests, values and practices between engineers and other societal actors [3]. Several engineering programmes have taken up this challenge [4] [5] and have enriched their curriculum with social sciences and humanities [6], or with transdisciplinary projects, in which engineering students engage with other disciplines and societal partners to address challenges [7]. Such courses and projects provide students with an understanding of the complex socio-technical nature of technology development and how they, from their discipline, can contribute effectively and responsibly.

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Understanding the complex relation between technology and society, and incorporating this in solutions that take both societal and technological opportunities and limitations seriously, is difficult. This becomes prominently visible in education on 'emerging technologies', i.e. technologies that bear a promise of contributing to the mitigation of grand challenges, but are still in an early phase of development, and inherently uncertain and ambiguous [8]. In projects on emerging technologies, students tend to deal with uncertainty by bracketing the societal complexity, acting as 'technocratic modernists' who push new technologies through society with technological roadmaps and 'tell & sell' implementation plans. They understand that there are technological uncertainties, public concerns, and competitive dynamics in play, but they often frame these as technical problems to be solved and as resistance to be overcome by better explaining the technology and its benefits to the people. The future then becomes a straight line of technological success and societal acceptance. For educators with ambitions to raise engineers who can effectively and responsibly cope with societal complexities, this simplified view is unsatisfactory [9].

In this paper, we present a novel educational method – a role-play simulation named Theatrical Technology Assessment – which aims to enable engineering students to explore and anticipate the complex socio-technical dynamics of emerging technologies. Conceptually, the role-play is rooted in Constructive Technology Assessment (CTA), a method that enables learning of real-world stakeholders from different disciplinary and societal perspectives around emerging technologies, and creates opportunities to steer and anticipate the development of new technologies and their embedding in society [10]. Using techniques from improvisational theater, Theatrical TA mimics and extends CTA in a role-play simulation. In this concept paper, first the outline of the role-play simulation will be presented. Subsequently a pilot study will be described, which was conducted with teachers and students of a bachelor's programme in Technology and Liberal Arts & Sciences, to explore what students can learn from this simulation. The paper will end with conclusions and directions for further research and development.

2 THEATRICAL TECHNOLOGY ASSESSMENT

2.1 CTA Background

Theatrical Technology Assessment has its conceptual roots in Constructive Technology Assessment. CTA was developed as a method for the prospective and reflexive steering of the development of emerging technologies [10] [11]. CTA aims to foster anticipatory learning among stakeholders in an early phase of the development, when options for steering are still open yet uncertainty and ambiguity prevails [12]. Stakeholder interaction in CTA takes place in workshops that are designed as 'micro-cosmoses', condensed representations of the stakeholder field. These workshops are 'bridging events' between 'enactors' and 'selectors' [13]. Enactors are promoters of a

new technology, such as engineers, scientists and entrepreneurs, who consider the development of the technology as progress and often identify with the technology [14]. Selectors, such as consumers, regulatory agencies and big companies, have a broader scope and evaluate various technological options in comparison. By staging constructive confrontation between enactors and selectors, CTA reduces the costs of 'trial & error' learning. It provides scientists, engineers and entrepreneurs with a basis to develop integrated plans for the societal embedding of their technologies, and gives stakeholders the opportunity to prepare for future developments and to steer technology in a desirable direction in an early stage.

2.2 Toward a role-play simulation

Role-play simulations are powerful means for students to learn about the complexity of technical and societal decision making [15] [16]. They enable students to experience stakeholder positions from the inside, learn to face conflicts with other stakeholders, and explore options for bridging the gaps between different positions and disciplines. A role-play can stage 'constructive controversies' [17] around alternative interests, problem diagnoses and solutions, and enable students to transcend these differences.

To make a role-play simulation into an authentic CTA-like learning experience, students need freedom to act in line with their stakeholder role, while a clear structure is needed to allow relevant and realistic stakeholder dynamics to arise [18]. It is important to include a variety of stakeholder positions, including enactors and selectors. Because students are not really stakeholders, the risk is that they only play on the basis of their assumptions about stakeholder behavior and opinions, which may result in interactions that have little resemblance with the world outside the classroom. As a role-play simulation needs a certain verisimilitude [18], role descriptions are required, based on research of the field, which stipulate what stakeholders want to accomplish and how they assess new technologies. Besides, knowledge of the state-of-affairs of the emerging technology and society should be enacted in the role-play to make it realistic.

To make the role-play simulation into an engaging learning experience, techniques from improvisational theater were used. Improvisation is characterized by 'yes-anding', which means that players accept each other's actions in the play as 'real' and build on that, resulting in quick interactions, path-dependency, and opportunities for path creation [19]. Adding improvisational theater to the role-play simulation can make students more confident in their roles and the interactions quicker. Improvisational theater allows for experimentation and adds to the dynamism and outcome variability of the simulation. Rather than trying to become 'almost real life' [15], the theatrical setting condenses and amplifies stakeholder interactions, which can make tensions more visible. Besides, it allows for jumps in time and stakeholder constellations.

2.3 Role-play simulation design

The purpose of the role-play simulation is to provide engineering students with insights on the complex societal dynamics around emerging technologies and on options to anticipate and steer this development. The simulation is designed specifically for a context in which students work on an emerging technology and its (future) development. The basic idea of this simulation is that the process and context are pre-structured by the teachers, but that the content is provided by a group of students studying an emerging technology. They decide which stakeholders will be in the role-play and which issues regarding the societal dynamics will be on the table. They make instructions for the players, articulate questions, and observe the role-play. We will call this group the 'instructor/observers'. The simulation will be played out by another group of students, the 'players'. There are two teachers involved. One is inside the role-play simulation as 'moderator', facilitating and steering the discussions, thus being the linking pin between the instructor/observers and the players. Another teacher supervises the overall process, starting and stopping the simulation, and leading the instructions before and the reflective sessions after the role-play.

The role-play simulation consists of two rounds of playing, one in which a CTA workshop is being mimicked and one which is a pressure-cooker later in time. Both playing rounds are preceded by a preparation phase and followed by a reflection and debriefing (cf. [20] [18]). A theatrical rehearsal phase is added to enhance the quality of the role-playing. Table 1 gives an overview of workshop protocol.

Table 1: Theatrical TA protocol

Preparation	15 min	• Players read role descriptions • Instructors/observers discuss questions with moderator
Role rehearsal	15 min	• Players rehearse persona with instructors
CTA workshop	20 min	• Moderator explains the aims and the set-up of the CTA workshop, acknowledges uncertainties related to the emerging technology, and stresses the need for reflection and steering in an early stage. • Participants discuss pros and cons, problems, opportunities, and preferences. • Participants question each other, explore options for aligning actions and finding consensus. • Moderator safeguards attention for the main questions of the instructing/observing group. • When saturation is reached, the discussion is closed.
Reflection	10 min	• What happened between stakeholders? What are learning points regarding technology and stakeholders?

		• Have questions of the observing group been answered? Which new questions pop up?
Coffee break & Preparation	15 min	• Players take a break. • Teachers and instructors/observers discuss questions, given their newly gained insights. • Setting is changed accordingly (e.g., time-lapse of 5 years, changed stakeholder constellation, adding facts).
Pressure cooker	15 min	• Moderator notifies players of changed circumstances, provides the task to make a concrete plan on a short notice (e.g., investment scheme, design). • Moderator leaves the table and joins the observers. • Players discuss and carry out their joint task. • Moderator returns and players present outcome.
Reflection	15 min	• Articulate learning points regarding socio-technical scenarios, stakeholder dynamics, plans of action, and the questions of the observing group. • Personal reflection of players on their role.

3 METHODOLOGY

3.1 Context

To develop and test this method, a pilot was carried out within the context of a semester project at the Technology and Liberal Arts & Sciences bachelor programme (ATLAS) of the University College Twente. This programme is an honours programme educating 'new engineers' [4], combining technology and social science to analyze complex societal problems and design solutions for a range of contexts [21]. The role-play was part of a semester project focusing on emerging energy technologies. Five project groups of about seven students were involved. They worked on molten salt reactors, piezo-electric roads, space solar power systems, AI grids, and solar updraft towers. They explored different disciplinary and societal perspectives related to their technology and were given the assignment to develop long-term socio-technical scenarios [22] and concrete short-term plans for advancing the new technology. The role-plays were positioned halfway this 9 EC project, when they had studied the technology, its context and potential developments, and were about to make choices regarding scenario and plans.

3.2 Design approach, data collection and analysis

For the design process we took a pragmatic approach [23], which involves going through multiple cycles of reflection-in-action on paper and in class [24] to create a working design. The process consisted of a series of small group discussions about the function of the workshops in the semester project and the opportunities for

mimicking CTA and using improvisational theater, followed by a co-creation session, in which a number of teachers, students, and improvisation consultant created the general set-up of the simulation. This format was finetuned and elaborated (including instructions for students) based on feedback of students and teachers.

After the role-plays, students wrote a concise report with their lessons learned, individually and as a project group. Besides, the project tutors and an improvisation expert observed the role-plays and evaluated it in a group discussion. The lesons learned of both students and teachers were coded using open coding [25], and categorized in different themes. The role-plays and teacher discussions were also audio-recorded, and these recordings were analyzed to corroborate and substantiate the themes, and to identify further points. The most prominent lessons are described in the results section.

4 RESULTS

4.1 Instructor/observers

What instructor/observers learned from the role-plays related to the specific questions and expectations about stakeholder dynamics they articulated beforehand. Students wanted to know, for instance, with which arguments an activist member of an NGO could be convinced, or whether stakeholders with opposite viewpoints could converge towards a large-scale or small-scale implementation of a certain energy source. The observers reported frequently that the role-play outcomes matched with their expectations, but each group also reported new findings, for instance related to the influence of a certain stakeholder, the seriousness of a specific tension, or novel solutions for social or technological problems. These new insights stemmed from the creative processes among the role-players. Particularly interesting in the light of the overall purpose of Theatrical TA were the insights related to the complexity and non-linear dynamics of the emerging technologies. This was the case, for instance, in the piezoelectric roads role-play, where stakeholder dynamics and the time-lapse showed the working of a 'hype cycle'. Because of the high expectations raised by the promoters of this technology in the first round of the role-play, all parties joined a pilot enthusiastically, but when the results were less than expected in the second round, most stakeholders were severely disappointed and abandoned the technology instantly. The group incorporated this into their scenario and plans by taking more time for pilots and urging the enactors of this technology to be more modest in their communication strategies.

4.2 Players

The playing students generally found the roleplays an enjoyable experience revealing relevant insights. A student who was quite skeptical at the start, wrote '*At the beginning, I honestly thought that this workshop would be useless, but I changed my mind halfway through. We had to make decisions the project group could not make*

themselves. We were able to do that because we are more objective and less involved than the project group'. Several students mentioned that it was revealing to act from the perscpective of a specific societal stakeholder rather than taking a helicopter view or acting from the standpoint of the engineer, which they would normally do in a project. A student wrote it was an '*interesting learning experience for me as it allowed me to see from the perspective of a single stakeholder and, for lack of a better word, be selfish and argue for my own interest as opposed to keeping all the aspects and perspectives in mind when forming an opinion*'.

The role-playing experience also increased the players' understanding of the complexities around emerging technologies. Students experienced, for instance, the differences regarding return on investment criteria between public and private stakeholders, or the different functions of pilot studies (learning about the technology vs getting media attention). The above mentioned hype-cycle in the piezoelectric roads case '*was really interesting to experience*', one student wrote, as she recognized how her arguments and opinion changed radically during the workshop. Another student found it fascinating to experience how much influence he could exert and how much he was trusted in his role as 'professor', especially when the discussion centered around technological uncertainties. Also negative experiences proved insightful. A student playing a citizen felt frustrated that she was marginalized and had little influence on the decision making. And a student who played a minister really felt the dilemma when he was urged to make a decision in a situation where so much was still uncertain.

5 CONCLUSION

In this paper we presented a novel educational method, based on insights from constructive technology assessment, improvisational theater and role-play simulations, which we coined Theatrical Technology Assessment. This method aims to enable engineering students to explore the socio-technical dynamics around emerging technologies and to provide insights they can incorporate in scenarios and plans that transcend disciplinary and societal boundaries. The results of the pilot indicate that this method can indeed have the intended effects. Both participating in the role-play simulation as a player and using the simulation to observe the interactions around 'your' technology provides novel and meaningful insights related to differences in stakeholder perspectives, ways to anticipate or transcend these, and socio-technical dynamics in general. These insights are relevant for the specific projects students work on, but also more generally, for their development into engineers that are competent in dealing with complex, uncertain and ambiguous technological and societal challenges.

The pilot corroborates that role-play simulations can be powerful means for students to learn about the complexity of technical and societal decision making [15] [16] [26] [27]. Several principles underlying this role-play design have been described earlier in

literature [18] [20], but they have been adapted to the transdisciplinary engineering context and the purpose of the role-play. What is novel in this role-play simulation is how students are involved. They are not only players and observers, but have an active role in shaping the content of the simulation and the flow of action. The use of improvisational theater strengthens the active role of the players. Techniques from theater have been used before in role-plays [28], but especially the improvisational aspect enhances the players' agency and the variability of the outcomes, which are important for the purpose of this role-play.

To further develop Theatrical TA, additional experimentation and a more elaborate evaluation of the effects on student learning is needed. This can be done in the context of projects on emerging technologies, but also in other projects on scenario development and courses on technology and society. In some settings, there will not be enough time to involve students as co-designers and instructors of the roles, which requires the development of cases that can be used more 'stand-alone', with students as players and observers. The learning outcomes may then be different. The broader application requires the development of a library of educational materials, including introductions to the technologies, role descriptions, fact sheets, and guidelines for teachers. One should beware of workshops with unidimensional roles and strict scripts, in which the interactions can be fully predicted, as the creative aspect and outcome variability of improvisation is core to this method.

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WHY DO DUTCH GIRLS DO NOT CHOOSE FOR SCIENCE AND ENGINEERING? A FOCUS ON GENDER STEREOTYPES AND A LACK OF FEMALE ROLE MODELS

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ABSTRACT

In The Netherlands, much stronger implicit and explicit gender stereotypes of science and engineering professions prevail than in other countries. Compared to 66 investigated nations, The Netherlands scores highest on gender-stereotypical images of science and engineering and lowest on influx of female students in STEM bachelors. To increase the number of students opting for science and engineering studies, many actions have been taken, one of which is the option to choose a Research and Design track at specific secondary schools (the O&O track at the Technasium schools). Although such efforts have resulted in a higher percentage of girls choosing a STEM-oriented track in secondary school, still only 27% of the girls that start a BA university program enrolls in a STEM-study. Possible reasons for this may relate to the implicit and explicit gender-stereotypical attitudes that prevail in The Netherlands and to a lack of female STEM role models. In this paper, we present the results of a qualitative interview study with pupils and teachers from Research and Design tracks at different secondary schools in The Netherlands. Results show that even in the Research and Design tracks at secondary school, pupils and teachers seem to be unaware of the importance of explicating the low influx of female STEM students and its relation to implicit gender stereotypical images and a lack of female role models. As a consequence, very few female STEM role models are provided to pupils and little conscious effort is put into countering potential gender stereotypes and stimulating girls to choose for science and engineering.

1 INTRODUCTION

1.1 Underrepresentation of women in STEM

In The Netherlands, the representation of women in science and engineering professions is low and much lower than in many other countries. International research has shown that an important reason for women's underrepresentation may be that, although we seem to have a gender-balanced culture, much stronger implicit and explicit gender stereotypical images of science and engineering professions prevail in The Netherlands than in other countries. Compared to 66 investigated nations (e.g., USA, Canada, Russia, Egypt, Australia, and Iran), The Netherlands scored highest on male gender-stereotypical perceptions of science and engineering and this correlated with the lowest influx of female students in STEM (Science, Technology, Engineering and Mathematics) bachelors [1]. According to the authors of that study, this may result in a loop effect: the high domain-specific sex segregation in The Netherlands, whereby male beta-scientists and engineers outnumber female beta-scientists and engineers nearly four to one in both educational and employment enrolment, results in a lack of positive female role models for girls, which in turn may reinforce gender-stereotypical images.

To remedy this situation, the past decade there has been intense policy action in The Netherlands to stimulate the choice of STEM subjects by secondary-school students. These efforts were partly successful. In the academic year 2018/2019, among the girls who were doing the highest level of secondary education (university preparatory education, VWO) 59% chose for an exam program that consisted of STEM subjects [2]. These girls form the prospective candidates for higher STEM education. Therefore, we would expect the increase in the popularity of the natural science & technology subject clusters at secondary school level to be reflected in the statistics of higher STEM-education. Although the percentages are growing (in 2019, 27% of all the girls who started a university program chose a beta-science or technology study path [2]), the number of girls opting for an advanced STEM higher education program is still much lower than we would expect based on the number of girls choosing a secondary school STEM program. It should also be noted that there are large differences in female enrolment between university programs. For example, of the students that started a BA program in 2018/2019 in computer science or mechanical engineering only around 13% was female, while these percentages were much higher for biomedical sciences (70%) or architecture (46%) [3].

1.2 The importance of female role models

Several international studies have shown that, in general, girls seem to lose their interest in STEM around the age of 15, but that an important way to bolster their STEM interest is to provide them with interesting and inspiring female role models (women working in STEM fields, women in STEM institutions, film or TV characters). For example, on average, across 12 European countries including The Netherlands,

41% of girls with female role models reported an interest in STEM study paths, compared to 26% of girls without female role models [4].

Although a review of the literature shows that there is a range of factors that may contribute to women's STEM choices (psychological, sociological, and educational factors), awareness and conscious countering of cultural stereotypical images is an often overlooked factor. Providing female role models and specifically stimulating girls to take up beta-technical topics may contribute to a more positive identification of girls with the STEM field [5]. Seeing a female exemplar who embodies traits compatible with how girls see themselves may engender the sense of belonging that girls need to become interested in STEM [6].

1.3 Research and Design Education

To increase the number of students opting for science and engineering studies, one action that has been taken is the option to choose a new Research and Design track at specific secondary schools. Usually, research and design projects are embedded in traditional science subjects as short-term projects. In 2004 a new initiative was launched to include a special O&O course (Dutch abbreviation for 'Onderzoeken en Ontwerpen', which means Research and Design). This track consists of research and design projects and is taught 4–6 hours a week to all grades in secondary education at so-called Technasium schools. O&O includes different fields of STEM (such as industrial engineering, ecology, etc.) and also includes non-STEM topics, it is entirely project-based and student-centered, and focuses on authentic research and design tasks, which are negotiated by real local companies and carried out in groups of students [7].

The main goals of the Technasium schools are (1) to prepare pupils for study paths and work in the beta-technical domain and (2) to stimulate pupils to develop themselves into competent designers and researchers. All pupils at the Technasium schools follow the track during their first three years of secondary school. After their third year, they can choose to continue the track until their final exams or to drop the course. Recent research showed that, in general, pupils in the O&O track reported more positive attitudes towards doing research and design activities than regular pupils. In addition, the same study showed that girls in regular schools reported significantly lower levels of perceived self-efficacy for research and design activities than boys did, but that girls who followed the O&O track reported similar levels of perceived self-efficacy as their male classmates [7]. Thus far, we do not know whether girls' increased enjoyment and perception of self-efficacy also leads to a greater intention to opt for a STEM bachelor at university level. The same study showed slightly higher future aspirations among boys and girls in the O&O track for design-related studies, but not for beta science studies and many of these girls seem to prefer to study medicine or architecture, rather than engineering, math or computer science.

One important aspect that has not been studied within the O&O schools is whether the assignments and projects specifically focus on countering cultural gender-stereotypes and providing positive female role models. Many schools seem

to think that aspirations to choose for a STEM study path will grow naturally, if pupils gain more experience and confidence in doing research and design activities. A review of the literature, however, shows that this is not necessarily the case, especially when cultural bias is strong [5]. Therefore, in the present qualitative pilot study we explored to what extent conscious effort is taken to discuss the role of women in STEM fields, whether girls receive enough female role models in the O&O track and are stimulated to choose specific beta-technical assignments, and whether the O&O teachers are aware of their role in stimulating girls in such domains. The results of this interview study may provide additional input to the discussion about the need for creating more awareness on gender-biases in STEM education.

2 METHODOLOGY

2.1 Participants

Focus group interviews were conducted with small groups of third-grade pupils (14-15 years of age) and their O&O teachers at five different Technasium schools in different parts of The Netherlands. A total of 26 pupils (16 boys and 10 girls) and 17 teachers (10 male and 7 female teachers) were interviewed by means of a structured interview format. Pupils and teachers were asked by their schools to volunteer in the interviews. In order to get a broad perspective, both male and female pupils and teachers were asked to participate. A procedure for active consent that complies with the ethical standards of the university was used. This means that teachers, parents and pupils were informed about the nature of the interviews and that they provided signed consent to participate. Teachers and pupils were interviewed anonymously; names and other personal information was not reported in the written summaries of the interviews. During their third grade, pupils need to choose whether they want to continue the O&O track and what type of exam program (STEM or non-STEM) they want to choose. Ten pupils were already sure to continue the O&O track, four were sure they would not, and twelve were not sure yet. The O&O track encompasses both STEM and non-STEM subjects and is taught by teachers from different disciplines. In our sample, nine teachers were STEM teachers (e.g., physics, biology) and eight teachers were non-STEM teachers (e.g., art, physical education, history). None of the teachers had completed a Master degree at university level, but they did complete their domain-specific Bachelor, regular teacher-trainer programs, and a special short course for O&O teaching (not a full O&O teacher-trainer program at university level).

2.2 Interviews and procedure

The present study was part of a larger study that also included interviews among pupils and teachers on higher-order thinking in O&O projects. In this paper, we only present our results on female role modeling. The types of questions in our interview format were of course slightly different for pupils and teachers, but were set up to be

able to compare the results among both groups. Each interview took about 50-60 minutes to complete and was held in a separate room in the school building during or just after regular school hours. For privacy reasons, interviews were not audio-recorded, but participants' answers were written down by the interviewers on a pre-structured form.

The interview format offered closed-end answers and opportunities for open-ended reflection and explanation of given answers. The questions focused on (1) attitude aspects (perceived importance of more women in STEM, perceived usefulness of female role models, and perceived importance of girls or female teachers to be role models or to raise awareness) and (2) on the extent to which respondents experienced deliberate focus on gender bias and female role models in O&O assignments (specific attention for women in O&O education, efforts to raise awareness for gender stereotypes in STEM fields, the occurrence of female role models or employees in the O&O assignments, the use of female exemplars through other educational materials or websites, the presence of female O&O teachers, and the occurrence of direct stimulation for girls to choose beta-technical assignments).

3 RESULTS

3.1 Pupils

Table 1 provides an overview of the closed-end answers of pupils and teachers. All pupils reported that they think it is important to have more women in STEM fields. Some pupils provided explanations that relate to the personal development of girls, such as: "Girls can be good in STEM as well", "Girls should at least try it", "It is basically men's work, but women could do it as well", or "Girls should feel that this is a possibility for them too". In addition, some societal reasons were raised, such as "Mixed groups generate better ideas" or "Women's thinking is different than men's, so this could lead to better solutions". At all schools, pupils commented that they thought that there were not enough girls in the O&O track (at one school there were 4 girls on 40 boys) and some pupils thought that girls might be reluctant to choose O&O because they might not have enough girlfriends in those classes.

None of the pupils could report specific attention for women in STEM during the O&O classes or assignments. In general, pupils observed that there were mainly male employees or clients responsible for the authentic assignments from companies.[1] Seven students reported some female company role models, but they commented that they were not necessarily related to STEM topics. Pupils predominantly reported that they doubt whether female role models would be useful in O&O assignments. Six students from the same school reported that they do think it would be useful, but other pupils commented that they think it would not

[1] This observation is in line with a quick scan that we performed on a random selection of 28 assignments from the complete database of O&O assignments (all theme groups) of the Technasium schools. Of these assignments, only one specifically mentioned a female client.

necessarily raise their interest for STEM. Half of the pupils reported having female O&O teachers, but many of those teachers were non-STEM teachers. Ten pupils (both girls and boys) reported that it was important to have girls as role models, but they commented that this was especially important for publicity at open days of the school to attract more girls to the O&O track. Sixteen pupils indicated that they never really thought about that.

None of the pupils reported that their teachers deliberately stimulated girls to take up beta-technical assignments. In addition, they did not report specific appreciation by their teachers for choosing beta-technical assignments. Some pupils commented that it was not specifically stimulated or appreciated, because they were free to choose the topics they like and that teachers' appreciation mainly concerned the way they carried out their assignments irrespective of the topic. At one school, pupils commented that the question was irrelevant for them, because they did not choose beta-technical topics anyway.

Table 1. Overview of pupils' and teachers' answers to the interview questions

	Pupils		**Teachers**		
	Yes	**No**	**Yes**	**No**	**To a certain extent**
Perceived importance of women choosing STEM studies and professions	26	0	8	6	3
Specific attention for women in O&O education	0	26	8	7	3
Raising awareness for gender stereotypes in STEM	-	-	2	13	2
Occasional female role models in O&O assignments	7	19	0	17	
Female examples through other educational material or websites	-	-	0	17	
Perceived usefulness of female role models in O&O assignments	6	20	12	3	2

Female O&O teachers (STEM and non-STEM)	13	13	12	5	
Perceived importance of girls or female teachers as role models or to raise awareness	10	16	13	2	2
Direct stimulation of girls to select STEM topics/assignments	0	26	2	15	
Perceived appreciation for girls' STEM choices	0	26	-	-	

3.2 Teachers

As shown in Table 1, less than half of the teachers reported that they think it is important that more women choose a STEM study path or career. Teachers in favor of this explained that this was important for girls' personal development, with similar reasons as the pupils had provided, such as "Women are equally good at STEM as men are", "Girls should keep an open mind", or "Girls should not feel reluctant to pursue a STEM career". In addition, they provided societal reasons, such as "Women bring in qualities to the STEM field that could improve things" or "There should be an even distribution of women and men in STEM, but this should also be the case in other domains, such as nursing". Teachers who did not think it was important to have more girls in STEM fields commented that prospective students can choose whatever they want, that they did not see it as their role as teachers to stimulate a certain direction, and that the O&O track encompasses all sorts of disciplines and is predominantly focused on doing research and design, irrespective of the domain.

Whereas pupils did not experience specific attention for women in STEM during the O&O classes or assignments, eight teachers did report that this was sometimes the case, but mainly when it popped up in class. Teachers were asked whether they thought they had a role in raising awareness for this issue, but only two teachers answered affirmatively. Reasons mentioned for not raising awareness were "I never really thought about that", "Pupils know this themselves, so I would only be reinforcing stereotypes", or "We think it is more important to raise awareness for the benefits of O&O in general". None of the teachers was able to specify how they deliberately created more awareness for women in STEM fields. In addition, none of the teachers could mention a specific female role model in the O&O assignments and none of the teachers ever used additional educational materials, such as specific websites targeted at women in STEM fields. The majority (12 teachers) did, however, think it would be useful if more female role models would be provided in

O&O assignments. And they also (13 teachers) thought that a female STEM teacher could be a role model. Several teachers did mention, however, that they were reluctant to stipulate the issue too much, because they thought they would be paying too much attention to stereotypes and they thought pupils would find this “irritating”.

Only two teachers reported that they deliberately stimulated girls to select beta-technical O&O topics, but as mentioned above, they did not specify how they did that. Reasons not to stimulate girls specifically were again that teachers did not want to highlight a stereotype, that they thought that they should not treat boys and girls differently, and that they wanted to comply with girls’ own interests, rather than stirring them towards certain topics.

As a last open question, teachers were asked whether they saw room for improvement, for example by altering the O&O assignments to include more female role models or to look for technical companies with a better gender balance. Some teachers responded that they never really thought about that. Some teachers mentioned that it could be possible with large technical companies that are open to the issue, while others responded that they thought it would be difficult, because they experienced difficulties finding companies with authentic assignments that they could use anyway.

4 CONCLUSION

The results of the present qualitative pilot study show that even in specific Research and Design tracks at secondary school, pupils and teachers seem to be unaware of the importance of explicating the low influx of female STEM students in The Netherlands and its relation to implicit gender stereotypical images and a lack of female role models in STEM fields. Although all pupils and half of the teachers thought it is important to have more women in STEM fields, it seems as if both groups do not see a role for themselves in this and that they think that boys and girls should feel free to choose the topics or study paths that interest them the most. Although this is of course a valuable opinion, at the same time it indicates that respondents seem to underestimate the power of implicit cultural gender biases and the positive potential of female role models to counter those biases. Several teachers specifically indicated that they did not think it would be wise to counter gender stereotypes and stimulate girls to choose for science and engineering, because they thought that this would emphasize gender stereotypes. The results have implications for the Dutch O&O tracks and for engineering education in general. Apart from making pupils more aware of their competencies in research and design, schools should also focus on implicit personal and societal attitudes towards women in STEM and on the benefits of positive female role models that may enhance girls’ identification with STEM studies and professions.

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THE CDIO APPROACH IN A FABLAB ACTIVITY FOR ENGINEERING EDUCATION PROMOTION

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ABSTRACT

The number of FabLabs has been steadily increasing over the last few years. Their main objectives are to sensitize its public on Science, Technology, Engineering, and Math (STEM) education through the digital manufacturing chain of an object and to allow the large public to make their own objects. Through, the increasing popularization of these advanced technologies, it becomes more difficult to establish the makers from the engineers.
The thinness of this distinction may have, in some cases, a negative impact on the promotion of engineering education. In actual engineering projects, a rigorous approach is usually followed such as the CDIO method. Meanwhile, the design rules pursued by the makers are not necessarily as systematic as the ones followed by the engineers.

In order to present this distinction to high school students, this paper illustrates the usage of a CDIO approach within the framework of a FabLab activity to promote engineering education. The proposed week-long activity concerns a personal loudspeaker construction using the resources and capabilities of a FabLab.
Furthermore, due to a precise number of turns in the windings, the manual construction of the speaker remains a considerably laborious task.
To solve this issue, the students are made responsible for proposing an innovative solution by applying a CDIO approach. This solution must lead to the design of a machine-tool manufacture dedicated to a loudspeaker production.

1 INTRODUCTION

1.1 Emergence of Fablabs

The maker movement is currently a global growth phenomenon. It regroups different profiles of makers that collaborate through various social exchanges sometimes online and sometimes in specific spaces using technological resources to produce objects. Fig. 1 shows an order of magnitude of this growth as well as the increase of meeting places for those makers over ten years [1].

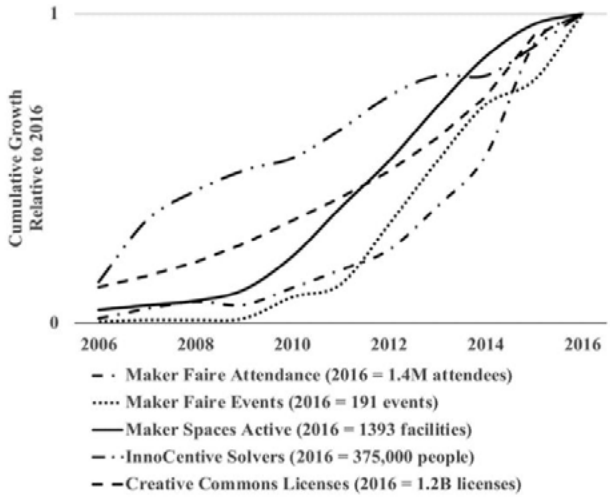

Fig. 1. Indicators of the global growth of the maker movement (2006–2016) [1]

This increase is due to the always growing financial accessibility of prototyping equipments, such as laser cutting, 3D printing or 3D scanning [2]. These low-cost tools are now accessible in different spaces such as hackerspaces, makerspaces and also FabLabs. The Fablabs are fabrication laboratories that guarantee to their members an access to different low-cost production machines. This initiative, created by the MIT physicist Nei Gershenfield in 2000, defines a charter with a minimum equipment to obtain the "FabLab" label. Nowadays, the FabLabs association has more than 1800 labelled fabrication sites. FabLabs constitutes also spaces for training and developing awareness regarding new technologies. Moreover, Fablabs are suitable for promoting STEM education through several activities [3]. Furthermore, makerspaces constitute a conducive environment for developing creative skills during engineering studies [4]. Unfortunately, the public within the FabLab is very heterogeneous which might cause

a lack of understanding of engineering studies in general. Indeed, the FabLabs community is made up of individual makers who are “Do It Yourself (DIY) hobbyists”, artists, crafters and engineers [1]. In engineering studies promotion, it is essential to distinguish the maker and the engineer among the young public. The aim of this paper is to propose a FabLab activity that distinguishes these two profiles with the help of CDIO approach. The main objective of this ‘Conceive-Design-Implement-Operate’ (CDIO) approach is to make the connection between theory and practice [5]. Fig. 2 illustrates the distinction between the two profiles based on the CDIO approach.

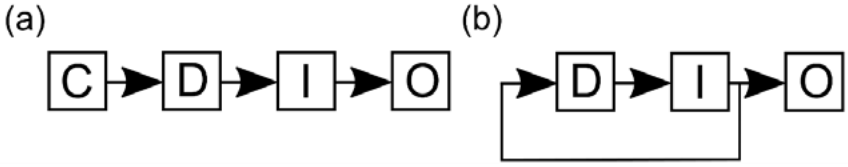

Fig. 2. Distinction between (a) engineer and (b) maker through the CDIO approach

Two points can be highlighted in order to help distinguishing these two profiles:

- **Conceive** is one of the most important steps in engineering. This consists in a comprehensive and precise study of the problem as well as the already existing solutions that provide a solution to each part of the problem.
- The **loop between Implement and Design** insists on the trial-and-error approach that highlights that the maker often obtains a solution by using an empirical approach.

This paper will try to highlight this phenomenon and its impact on the promotion of engineering studies through the feedback of the participants of the proposed FabLab activity.

2 DESCRIPTION OF THE ACTIVITY

2.1 General context

A week long activity is proposed to the students to illustrate the application of CDIO approach in different engineering domains and, especially, in Mechanics. This consists of an ex-nihilo loudspeaker construction using resources and capabilities of our FabLab.

The winding operation of the loudspeaker electromagnet remains an important step of the processing. It consists of winding a large number of turns of a copper wire in order to form a coil. The length of this copper wire can be up to 30 meters. Therefore, the winding step can rapidly become tediouswhile manually carried out.

The proposed activity is then to Conceive, Design, Implement and Operate a machine-tool manufacture dedicated to the production of winding coils until the realization of a loudspeaker.

2.2 Week-long activity organization

This week is actually organized in 4 days; each one being dedicated to one step of the CDIO methodology. During these days, the students have the opportunity to practice different disciplines of engineering, for example CAD modelling and also micro-controllers programming using Arduino boards. The students are grouped in teams of four people; each team designing its proper winding machine.

First day - Conceive

The first part of the morning is dedicated to a "icebreaker" activity allowing the participants to introduce themselves.

In the second part of the morning, the aims of the traineeship are presented and a dimensional study of the loudspeaker is carried out which allows us to determine the number of turns necessary to obtain a 8 Ohms resistance electromagnet winding (25m wire with approximately 400 turns). Each team should then manually performs the winding of the coil and measure the corresponding time this operation takes (approximately 10 min). The aim of this manipulation is to raise the students awareness about the interest of designing an automated machine-tool.

The afternoon is dedicated to the conceive part of the CDIO approach. Without knowing the material put at their disposal, each team performs a brainstorming that must lead to a technical solution. In the requirement specifications, it is imposed that their solution should allow a honeycomb winding methodology The students must research online for some usual existing mechanisms or potential solutions, especially for transforming a rotating motion into a periodic translational motion.

After a short reflection, all solutions are exposed between the different teams. Then, a general discussion takes place in order to examine the advantages and drawbacks of each solution. Merging all ideas leads to a unique technical solution that should be implemented by all teams.

Second day - Design

The morning of this day is devoted to CAD software initiation using SolidWorks. The students are expected to model the loudspeaker for which technical drawings are provided.

In the afternoon, the spare parts that allows the loudspeaker construction are provided to the teams. It contains an electrical motor, an Arduino kit, gear sets, threaded rods, screws, springs, bolts and nuts. Each team must then realize the technical assembly drawing of their winding machine. The important aspects that must be taken into

account in the mechanical design are the gears coaxiality and the geometry of the wobble plate which oscillates and control the amplitude of the translational motion.

Each member of the team freely models with SolidWorks an element of the winding machine while respecting the requirement specifications. The assembly of the different parts of the system is then carried out to verify that all dimensional constraints are met (Fig. 3).

Fig. 3. different CAD models of the slide bearing frames and Solidworks assembly of the winding machine

Third day - Implement

It is dedicated to the manufacturing of the different constitutive elements of the winding machine. Some parts are made by 3D printing (such as the loudspeaker, the wobble plate or the thread guide) and others using laser cutting (such as the base plate and some slide bearing frames). We use laser cutting as much as possible since the corresponding manufacturing time is of the order of a few minutes while 3D printing can takes several hours.

During the 3D printing of the different parts, an introduction to Arduino programming is carried out. Student develop an Arduino program that controls the DC motor and measure the number of turns with an optical forked photoelectric sensor.

Last day - Operate

The morning is dedicated to the winding machine assembly and the production of one speaker coil. During the afternoon, the students implement a low voltage audio power amplifier using LM386 electronic component. At the end of the traineeship, each student can bring back home its own speaker and connect it to its smartphone with a jack plug to listen its favourite songs (Fig. 4).

Fig. 4. Assembly of the winding machine

3 RESULTS

It is always difficult to quantify the gains from an educational activity. The evaluation proposed in this paper is based on responses to a compulsory survey conducted after the traineeship. This survey has items common to all organized stages as well as items specific to the activity treated. Fig. 5 summarizes the responses of the students who participated to the stage described in this article. The students had three different choices for each evaluated point: *Done and I liked it, Not done but I would have liked it, Not done but without opinion*. It can be seen in this Figure that all of them constructed the machine tool and appreciated the realization of this general engineering project. The CDIO approach was an important part of this one. This self-assessment shows that the “Conceive” step has been well received by the students through the Project Making. The main objective of differentiating maker and engineer is thus achieved. In addition to this assessment, many learnings have been done, both technical and human. These learnings, that have not been measured, are:

• The development of the spatial vision using 3D software, plans, real manufactured objects and the link between them.

• The reinforcement of basic ideas in electricity and electronics that were not largely developed in Belgian secondary teaching.

• Taking technical constraints into account to produce an object but also to manufacture it.

• The teamworking qualities such as active listening, positive criticism, weight of arguments,

Over the last two years, 7 students out of 12 entered the Faculty of Engineering. Even if they were already interested in engineering studies, more than 50% of the participant decided to become an engineer to complete their maker profile.

To conclude, the activity proposed during this four-day internship seems to meet the objective of promoting engineering studies in the maker community but more broadly, softly develops useful skills of all participating students.

In perspective, new self-assessment indicators need to be defined, and this activity needs to be repeated to increase sampling to confirm the tendency.

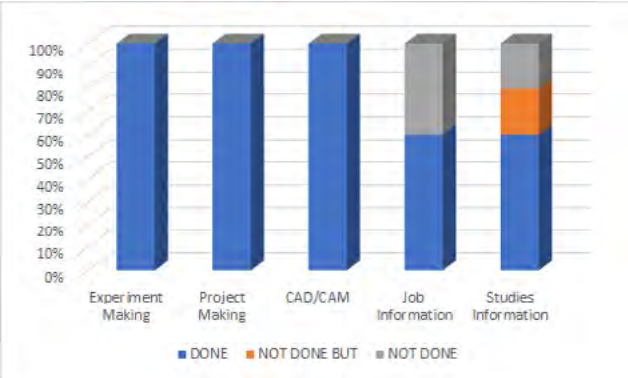

Fig. 5 Internship feedbacks

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ATLAS UNIVERSITY COLLEGE TWENTE: A NOVEL APPROACH IN INTERDISCIPLINARY ENGINEERING EDUCATION

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ABSTRACT

ATLAS University College Twente offers a residential, interdisciplinary engineering program that aims at educating the 'New Engineer.' The program has embraced the concept of self-directed learning, meaning that students attain most of the program's learning goals in their own way. ATLAS is organized in semesters, each with their own specific learning goals. These so-called semester goals define a framework that allows students to build their own academic profile as New Engineers and, at the same time, safeguards that all students reach the intended learning outcomes of the program itself. One of the core values of the program is *integration*. Students follow mandatory courses in the domains of mathematics, natural - and social sciences, and work in interdisciplinary projects. ATLAS also offers interdisciplinary electives, designed and executed by teachers with different disciplinary backgrounds. Moreover, students are encouraged to use their extensive elective space to further build up their interdisciplinary profile as New Engineers. The program was successfully accredited in 2018 and is in a continuous state of development and innovation. This contribution discusses the set-up of the curriculum, its interdisciplinary components, its radical educational approach, assessment method, and future program developments and challenges.

1 INTRODUCTION

1.1 Kick - off

The academic year 2013 – 2014 marked the start of ATLAS, a Bachelor of Science degree program in Technology and Liberal Arts & Sciences. Twenty-six first-year students started their Freshman project in which they set out to bust an urban myth, for example: "Is a garden trampoline really a viable alternative to a Browder life net?" Discovery Channel's *Mythbuster* Jamie Hyneman introduced the students to their first project via a video link. Two years before, founders of the program Kees Ruijter and Jennifer Herek visited different faculties and departments of the University of Twente (UT) in search for members of what would form the core team of ATLAS.

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This team laid the groundwork for the program and began executing it. The ATLAS core team is still in place, including teacher members that were there from the beginning and new members, all with various academic backgrounds and nationalities.

1.2 The need for New Engineers

Innovation in engineering education has been the subject of heated discussions over the past 20 years (Kamp, 2016). It is thought that the combination of technology being a dominant force in society and the challenges the world is facing today should have consequences for the way we educate engineers. Today's breakthrough technologies seem to cross traditional disciplinary boundaries, implicating modern engineering solutions require an integrated perspective, especially in the way technologies are introduced into and affect society (see e.g. Bammer, 2013). They require a new kind of engineer (Goldberg, Somerville & Whitney, 2014).
Since the sixties, the UT has had a pioneering mindset in engineering education. Inspired by the Liberal Arts & Sciences programs of the Dutch University Colleges and the educational practice of new engineering programs worldwide, like Olin College of Engineering (Needham, Massachusetts), the UT launched ATLAS, an engineering program for New Engineers.

1.3 The ATLAS vision on the New Engineer

The core team that developed ATLAS created a visionary profile of the New Engineer containing five core values that stipulate how ATLAS Engineers are different from engineers educated in more traditional programs (UCT, 2018). These values concern *integration, trailblazing, community, self-directedness and excellence.* The profile describes that ATLAS engineers are equipped to solve challenges of our time that require the integration of perspectives from a wide variety of fields. Trailblazing their way, they dare to take a step into the unknown, pursue radically new solutions, take the initiative, while being open to innovation, creativity and novelty. They approach the world as a community and create and research with that community and for that community. ATLAS engineers are agile, have an open, independent and critical attitude, and are life-long self-directed learners. They strive for excellence; they have an urge to improve themselves and the ability to focus and persist on a topic or skill to reach and utilize their full potential.
This profile, in combination with the academic criteria for bachelor and master curricula (Meijers, van Overveld, & Perrenet, 2003) and the Domain Specific Frame of Reference (DSFR) that was developed for Liberal Arts & Sciences programs in the Netherlands, shaped the Intended Learning Outcomes of the program. The DSFR framework, based on more than 15 years of experience with Liberal Arts & Sciences education in the Netherlands, is aligned with European and international Liberal Arts & Sciences networks, assuring the connection with the expectations and requirements of the international educational field (UCT, 2018).

2 SET-UP OF THE CURRICULUM

2.1 Semester structure

The set-up of the ATLAS curriculum is straightforward with only two components: semesters and Personal Pursuits. Semesters have a study load of 27 credits and Personal Pursuits bear 6 credits. Each year contains two semesters and one Personal Pursuit.
Semesters are the main building blocks of the curriculum. Each semester has semester goals that, across all semesters, build up to the Intended Learning Outcomes of the program. All students need to reach these semester goals. Semesters one through four have the same set up: each contains a project, courses in different academic domains (natural sciences, social science and mathematics) and room for electives (starting in semester 2). The projects and domain courses are organized by ATLAS and followed by all students. Semester five is the semester "beyond ATLAS". Students then only take courses outside of ATLAS at another faculty of the UT or another (national or international) university. Semester six is the final semester. It is a signature semester with a Capstone project and elective courses that students attune to their own academic profile as a New Engineer. The elective space gradually increases throughout the program. At the minimum, students spent one-third of the program on electives.
Taking electives is not a goal in itself, it is a means to reach certain semester goals. For example, one of the semester goals in semester 3 states that students "*Demonstrate deepening of academic competencies in domains or fields that are relevant to their intended profile as a new engineer.*" It is clear that this goal can be met in different ways, depending on the direction students are taking. Electives then are a means to demonstrate deepening of academic competency in domains or fields that are relevant to them. It is in the way this type of semester goals is reached that the program becomes personalized, allowing students to create their own profile as a New Engineer. At the start of each semester, students present a plan on how they intend to reach the semester goals. The program sees to it that these plans meet appropriate academic standards (see paragraph 4).

2.2 The Personal Pursuit

The Personal Pursuit encourages students to turn their personal interests into an integral part of their academic development and is a unique Liberal Arts & Sciences part of the ATLAS program. Each year, students work on a project (6 credits, which equals 168 hours of work) that fully stems from a personal interest; something they have always been interested in doing, investigating, or designing. Students write a proposal describing their goals, planned activities, outreach to the community, and intended evidence to prove that they met their goals. The Personal Pursuit proposals are assessed by a special committee, safeguarding the academic level of the pursuit. Students have been working on subjects like synesthesia and forensics, photography, fiction writing, learning a new language, composing music, clothing design, motorcycle repair, and woodworking for their Personal Pursuit projects.

3 INTERDISCIPLINARY COMPONENTS

One of the core values of the New Engineer is *integration*, which relates to the ability to function as the linking pin in a team of experts with different disciplinary backgrounds and be able to cross disciplinary boundaries in solving complex problems. In different ways, the ATLAS program lives up to this value.

3.1 ATLAS admission procedure

Obviously, incoming students know what they are up to. Information available for them clearly explains what the program is about and during Open Days, Student-for-a-days and so-called In_Sight Days, prospective students learn about and experience the aims of the program. As part of the admission procedure, interested students are interviewed by both teachers and ATLAS students. An important topic of the interview is to learn about the students' interest in different academic disciplines and their vision on what is needed to solve the grand challenges of the world as New Engineers.
During the In_Sight Days, prospective students collaborate on preparing a mitigation plan to solve a complex problem (e.g. how to prevent temperature rise in big cities or mitigate the adverse effects of sinking cities like Jakarta). Based on this experience, they reflect on working on this type of collaborative projects. ATLAS teachers observe the collaboration process and give feedback on the proposed mitigation plan.
The students' reflections, the teachers' observations and the interviews are, amongst other things (school performance record, motivation letter, student resume) input for the decision of the admission committee. In this way, ATLAS aims to admit students who already have a certain affinity with integrating different disciplinary perspectives in an engineering context.

3.2 ATLAS domain courses and modelling

In the first and second year of the program, ATLAS students develop literacy in three domains: natural science, social science and mathematics. They follow mandatory courses in these domains, developed by the ATLAS core team of teachers. On the one hand, the contents of the courses are aligned with requirements for existing master programs, on the other hand teachers in these courses collaborate in creating a learning experience that supports integration. One example of this, is the focus on *modelling*. In the first semester, modelling is introduced as an aspect integral to all academic disciplines. Using modelling as a framework, students discover how experts from different domains try to understand real-world phenomena. It is thought that this fosters their ability to integrate. For an example of the use of modelling across domains in education, see English (2009). Eisenbart, Gericke and Blessing (2017) have advocated to use modelling in the interdisciplinary design process.

3.3 ATLAS interdisciplinary projects

In the first four semesters, students work on projects in groups. The nature of the projects becomes increasingly complex in the sense that the challenge they work on becomes more extensive and the number of stakeholders involved grows. For example, students in semester one might work on developing a new type of walking bridge for children with cerebral palsy, while students in semester four work on a

plan to mitigate the effects of extreme famine in Southern Africa. In the projects of semester two and four, students contribute from a personal interest (semester two) and from their own developed expertise (semester four). This is another way to scaffold the need to integrate. In the students' Capstone project (their bachelor thesis), students are further encouraged to develop their integrative ability. To support this, ATLAS encourages students to choose supervisors with different disciplinary backgrounds.

3.4 ATLAS integrative electives

A recent development, inspired by our colleagues from Olin College (Needham, Massachusetts), is the development of ATLAS integrative electives. The idea behind these electives is that teachers with different disciplinary backgrounds teach about a subject which links the disciplines. One ATLAS teacher in physics and one in social science developed a course with the elusive name "Sensors and Sensibility" in which they focused on the use of physical sensors (e.g. blood pressure sensors or galvanic skin response sensors) for studying mental states (e.g. fear or arousal). The course focuses on how the sensors work, but also on how social scientists use sensor data to measure certain mental states. Studying the reliability and validity of these measures calls upon the ability to integrate knowledge and insights from both disciplines. Of course, developing the course also helped the teachers to become more informed on each other's discipline, fostering their interdisciplinary abilities.

3.5 Creating their own profile as a New Engineer

In different ways, ATLAS stimulates students to work on their integrative abilities. From the admission on, ATLAS wants students to become New Engineers. Therefore, it is expected that students use their extensive elective space to pick courses from different academic disciplines. To safeguard that the choices they make are not random, ATLAS offers a developmental framework which scaffolds the build-up of their own interdisciplinary profile as New Engineers. This system is explained in the next section.

4 RADICAL EDUCATIONAL APPROACH

ATLAS has adopted the concept of self-directed learning (Gibbons, 2002; Pintrich & Zusho, 2002; Saks & Leijen, 2014). Each semester sets a developmental framework with semester goals that safeguards that each student can reach the Intended Learning Outcomes of the program. However, the semester goals can be attained in different ways, depending on the interest of the student. Other program requirements, for example doing the interdisciplinary projects in semester one till four, are also part of the framework. Self-directedness in the program (another core value of the New Engineer) concerns making curricular choices and taking responsibility for your own learning. At the start of each semester, students reflect on their interests and direction and make curricular choices to pursue those interests, within the boundaries of the developmental framework. The choices they make culminate in a plan (a Personal Development Plan; PDP) that needs approval. In the plan, the students also explain how they will prove they met the semester goals. To this end, they propose certain evidence (defined as student work combined with expert feedback) that shows they met the goals. The fact that, to a large extent,

students can attain the semester goals in their own way, gives them the opportunity to create their own interdisciplinary profile as a New Engineer.

5 ASSESSMENT METHOD

The concept of self-directed learning does not fit easily within the frameworks and indicators used for quality assurance in higher education in the Netherlands. The Dutch Higher Education Act (Dutch Government, 2020) is implicitly geared towards a model of prescribed courses that are uniformly assessed and, together with a thesis, make up a curriculum. In this model, quality assurance relies heavily on guarding the quality of assessment as carried out by the teachers. ATLAS has, for a large part, made students responsible for the design of their assessment plan. The challenge for ATLAS is to find a way to assure and account for the quality of assessment in such a way that it still affords self-directedness, meaning allowing students to make their own curricular choices to build up a unique profile as a New Engineer.
ATLAS its solution for this challenge lies in the so-called “PDP-MTE-SER” cycle. As said, the PDP contains the students’ curricular choices, including an assessment plan. In a Midterm Evaluation (MTE) halfway the semester and the Self Evaluation Report (SER) they produce at the end of the semester, students reflect and evaluate to what extent they have reached the semester goals. Assessment of students is based on whether their self-evaluation can be justified. Because the choices students can make to reach their goals are diverse, ATLAS needs to continuously monitor and calibrate these in order to safeguard the quality of education and assessment.

This is what students say about the ATLAS approach:

“Even though we have always had all the freedom to set out our own path, we have always been perfectly aware that not every hodgepodge of course selections will lead to a perfectly balanced multidisciplinary profile. Students know they have to connect every course of interest to an idea of how it adds to their academic profile – and the structures that have been put in place to ensure this are greatly valued by your students (UCT, 2018).”

The program was successfully accredited in 2018. To show that the program achieved its learning outcomes, the assessment of the capstone projects was taken as an indicator. Of the 60 capstone projects that had been assessed up until then, 63% were rated as very good or excellent, 25% as good and 12% as sufficient. These assessments were done by external supervisors, indicating that the program is successful at educating students to a Bachelor of Science level. Another indicator related to entrance to master’s programs. Of the 60 graduates that were tracked for the accreditation, 65% had started the master of their choice directly, while 5% required some form of bridging course before they could start their master (30% took a gap year, for reasons ranging from entering engineering competitions, work, board work or travel). Of the graduates that entered a master either directly or after a gap year, 94% were admitted directly into the master of their choice. The universities they were admitted to include prestigious universities like ETH, Imperial College London, University of Edinburgh, and University College London. The master programs range from purely natural science (e.g. Quantum Physics at University of

Copenhagen), to mathematics (e.g. Machine Learning at Aalto University), to classical engineering (e.g. Micro & Nano Systems at ETH), to new engineering (e.g. Sustainable Development at Universities of Graz & Venice), to social science (e.g. International Relations & World History at the University of Nottingham in China). This was considered proof that the program is successful in educating students to a Bachelor of Science level in their chosen academic profile while maintaining the Technology and Liberal Arts profile.

6 FUTURE PROGRAM DEVELOPMENTS AND CHALLENGES

The ATLAS program is still “engineering its education.” Not only because of the radical new approach that is constantly put to the test while the shop is open, but also because the core team of teachers are becoming experts in interdisciplinary education more and more, and therefore keep developing better ideas on what New Engineers need and how to deliver that. To conclude this paper, we want to address the main areas of development and some challenges the ATLAS core team is facing.
First, the core team members realize that to be able to deliver interdisciplinary education, they have to become more interdisciplinary themselves. The importance of collaboration and integration obviously applies just as well to them as to the New Engineers they educate. While several core team members work in the program part-time and the execution of the program is time-consuming, team development is relatively slow in this respect. Currently, new core team members are being appointed which will hopefully speed up this development
Second, ATLAS wants to grow, but needs to think about how a higher influx will affect the quality of education (ATLAS currently has an influx of approx. 50 students per year). For their own courses, ATLAS teachers provide extensive feedback, which is time-consuming. Also, student-teacher learning interactions are highly frequent, both inside and outside the classroom. While this affects learning positively (see e.g. Hattie, 2092) and is highly appreciated by students and teachers alike, upholding these dynamics when more and more students enter as first-years will be a challenge.
Thirdly, now ATLAS is in its second lustrum and was successfully accredited in 2018, the core team of ATLAS has become more aware of the privilege given to them by the UT to independently develop a program that is unique in many aspects. Despite the challenges described earlier, ATLAS also wants to start sharing its educational experiences with the engineering education community and invest in educational research so that ATLAS does not become a well-hidden secret, but a driver for further development of engineering education.

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IMPLEMENTATION OF DIGITAL LITERACY COURSE IN THE FIRST-YEAR ENGINEERING STUDENTS' CURRICULUM

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Conference Key Areas: *Future engineering skills, E-learning, blended learning, virtual reality*
Keywords: *digital literacy, blended learning setting, BYOD*

ABSTRACT

Digital Literacy has become a key skill for 21st century engineers that corresponds to the demands of Industry 4.0. On the other hand, the Digital Literacy level has an impact on learning process at university, including engineering curriculum, learning practices etc. In our work, we describe an example of integration Digital Literacy course "Information and Communication Technologies" in the curriculum of first-year engineering students. This course was designed by using blended learning strategies as well as BYOD (bring your own device) technology. We emphasize that the inclusion of such course in the curriculum fosters the development of digital literacy skills of first-year students and create the preconditions for the formation of an effective personal learning environment. The research question was to evaluate the level of digital literacy of freshman students and analyze the Digital Literacy Course impact on students' preparedness to use the ICT during the learning process. Such course was implemented for the students of different specialties. It gave a possibility to analyze the differences between engineering students and representatives of other specialties. The survey was carried out which includes the question related to tools, which students use during the lessons. The purposes of different tools using including teamwork and problem solving have been analyzed. As a result, the improvement of Digital Literacy skills of first-year engineering students was observed.

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1 INTRODUCTION

Development of Industry 4.0 has a profound effect on modern engineering. Digital transformation is accompanied by the accelerated introduction of modern technologies and creates conditions for changing business models and accelerating innovative development. The driving factors behind the transformation of jobs are the widespread adoption of high-speed mobile Internet, the development of artificial intelligence and its applications, and the widespread use of big data and cloud technologies. The introduction of innovative technologies into the practice of engineering is intensifying, including Big Data Analysis, Internet of Things, Machine Learning, Virtual Reality, etc. New job trends include the increasing flexibility of the labour market, the decentralization of work operations and the increasing share of remote workers [1].

The above factors determine the relevance of the development of digital competence of engineering students since the first years of study. The CDIO Standards 3.0 proposal states, "Digitalization can be argued to be a major enabler for reforming both engineering work and ways of learning how to engineer." [2, p. 3]. Thus, the current level of digital competence for first-year students is an essential prerequisite for their successful inclusion in the educational process at the university and the formation of personal learning environment (PLE). The educational process in higher education is focused on a higher level of autonomy and responsibility, an active role of the student in building their educational trajectory, intensive interaction of students in groups in the course of completing tasks of both online and offline communication. In our opinion, timely and sufficient assessment of the current level of digital competence of first-year students will help solve the problem of adaptation.

Also, one of the challenges for higher education is to encourage students to use the learning approaches that lead to the highest quality learning outcomes and develop flexible competencies. In this paper, we are talking about research conducted during the academic semester and aimed at improving the quality of education of students of various specialities in the implementation of digital technologies and services for the course "Information and Communication Technologies" (ICT). Although the study of certain aspects of students' digital competence required for further professional and educational development was conducted within one course only, a wide range of subjects for which discipline was read and different types of samples led to statistically significant improvements in the quality of students' learning approaches.

In this paper, we present the on-going experience and preliminary findings concerning (i) the design and implementation of integration Digital Literacy course "Information and Communication Technologies" in the curriculum of first-year engineering students, (ii) the investigation of the influence of this course on the development of digital skills of first-year engineering students as well as their preparedness to the formation of own PLE. Due to the fact that a similar course was also introduced for students of natural sciences and humanities, we were able to compare the results and highlight those areas that need further improvement specifically for engineering students.

2 THEORETICAL BACKGROUND

The use of Digital Literacy concept has been widespread since 1997 when Gilster defined Digital Literacy as 'literacy for a digital age' [3]. Since then, the both terms

Digital Competence and Digital Literacy have been increasingly referred to as official documentation of government agencies and international organizations, and indeed in scientific researches [4].

In 2006, the European Commission recognized Digital Competence as one of eight key competencies for lifelong learning. It emphasized the critical connection of Digital Competence with such areas of human life as employment, training, leisure and socialization. For the time being, the EC Digital Competence is following: "digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society". The Digital Competence framework consists of 21 competencies divided into the following five areas: information and data literacy; communication and collaboration; digital content creation (including programming); safety (including digital well-being and competencies related to cybersecurity) and problem-solving [5].

It should be noted that the structure of Digital Literacy/Digital Competence and approaches to describing it, presented in research publications, vary, which allows us to interpret the term as an umbrella term. Thus, when defining Digital Literacy, researchers refer to the ideas of cognitive skills and competencies, the importance of critical thinking and high-level thinking skills, and not only to the level of development of technical skills in computer technology [4, 6].

In the educational process, Digital Literacy is interpreted as an important prerequisite that determines students' readiness to successfully learn in the context of online and offline learning integrations, be flexible and adapt to change (which has proven relevant in recent months as students in most countries have gone online to study). Learning about and with digital technologies is defined as one of twelve different areas of Digital Competence [7]. As experience shows, among the educational practices having a positive impact on the development of advanced Digital Competence, researchers and practitioners highlight evidence-based practice, problem-based learning, case-based learning, project-based and design-base learning. Also, Graham defines four key characteristics of engineering programmes: a combination of digital and student activating learning forms, educational arrangements with a high degree of flexibility and diversity, global and multidisciplinary elements, as well as design projects that at the same time offer opportunities for reflection on technology development and own learning [2, 8].

The combination of active learning and digitization is provided within the blended learning framework that was used in our course. It is worth noting that the impetus for the study was due to two reasons. First, teachers are dissatisfied with the level of digital competence in the distance and blended learning. Second, an analysis of students' perceptions of modern information technology to work as a team, to solve problematic tasks and to study showed that 96% of students use smartphones [9] for training and personal use. Looking at Learning Management Systems (LMS) statistics in the United States, over 60% of students use LMS effectively in each discipline learning.

The situation in Ukraine is far from the same. As practice shows, first-year students who come to study from major cities have some experience with a variety of training systems and cloud services. Still, most have only a distant understanding of working online, of teamwork in electronic applications to solve problematic tasks effectively.

Moreover, first-year students do not understand the basic principles of Digital Literacy for learning.

We invest in the concept of Digital Literacy a little more than an individual's ability to evaluate and systematize information using information technology [10]. Digital Literacy ranks second among important 21st-century skills that modern professionals need to possess. The ability to use advanced digital technologies effectively and safely in work and study is Digital Literacy. That is, this can also include the understanding of secure online interaction, the ability to extract information that is irrelevant or that may contain plagiarism. In this case, the specialist must also produce reliable data, be able to simplify and interpret the information in a convenient way for the user. And for this, he must use services and technologies that are close to the average citizen (infographics, videographics, animated 3D drawings, which easily display information on mobile devices) [11]. It can be concluded that Digital Literacy is based on the concepts of visual, computer and information literacy [12].

3 COURSE DESCRIPTION AND METHODOLOGY

The prerequisites for the importance of Digital Literacy have been used as the basis for a study conducted for the ICT course. Such course was included in almost all degree programmes at [name of university] since the 2019–2020 academic year. For various specialities, it is offered in the first or second semester. This course has a total of 3 credits from the ECTS, which is equivalent to 90 hours. The study was conducted for 130 students, among them, 60 students are of humanities, and 70 students are of engineering and applied physics specialities.

Our research is work-in-progress. Therefore, the choice of the case study method was based on the fact that the ICT course was introduced for the first time, so our activity was primarily aimed at accumulating empirical data. It is assumed that these data will help to answer the research questions, and will determine the further university strategy for creating the conditions to form a digital competence (Fig. 1) in students.

According to the scheme, the topics students studied during the semester included: creating a personal e-learning environment (review of LMS, Google applications for data management automation and storage), organization and teamwork support (the concept analysis of the project and its components, time management, collaboration and services that provide project management and further communication between team members), the concept of digital literacy and Internet safety (rules review of online interaction, services of testing their own digital literacy after writing Ukrainian and English texts), the concept of academic integrity (data analysis and services review for plagiarism), data search, analysis and systematization (scientometric databases, managing of scientific texts, creating a scientific profile and searching for information by keywords and other means in the network), work with the content management services (creating documents with different data formats, working with online Google spreadsheets, creating presentations and knowledge maps in various cloud services), applications for the research and projects presentation (review of preparation tools, rules for successful presentation, apps for creating info- and videographics, videos). All topics focused on tools, cloud services and programs that will help students learn the information and communication technologies essential to support their educational process at the university and after its completion. Due to this

selection of topics, we were able to significantly increase the level of digital literacy among students after the course.

All practical tasks provided by the course were divided into two categories: mastering the technical skills of owning services and Internet applications and tasks for the high-level thinking skills development: creativity, critical thinking and problem-solving skills. Practical tasks that develop critical thinking, students' creativity and the ability to solve problems were mostly performed during classroom work. There were a few common practices we used in our classes: the "World Cafe" method for the problem analysis and ways to solve it, the "Why?" method for structuring the problem-solving aspects, the marshmallow challenge for testing inclusion in teamwork, the "Disney's Three Chairs" task, which develops creativity while finding solutions to a problem. The online part included technical tasks, which involved the skills of online services and programs acquirement. Before this, theoretical aspects and issues of the application functionality were covered in the classroom.

The level of tasks complexity was determined by how many applications had to be considered when studying one topic, the number varied from 3 to 5 tasks. Besides, the issues were formed in accordance with Bloom's taxonomy, which provided for a gradual increase in the level of individual aspects complexity of each task. For students who studied in non-technical specialities, from time to time, it was challenging to perform some tasks on time, due to lack of knowledge of working with standard services and Internet applications.

All methods ensured the fulfilment of the research goal, which was to improve students' digital competence in the ICT subject, using aspects of approaches to blended learning and project activities. In the case of our study, qualitative and quantitative data were used.

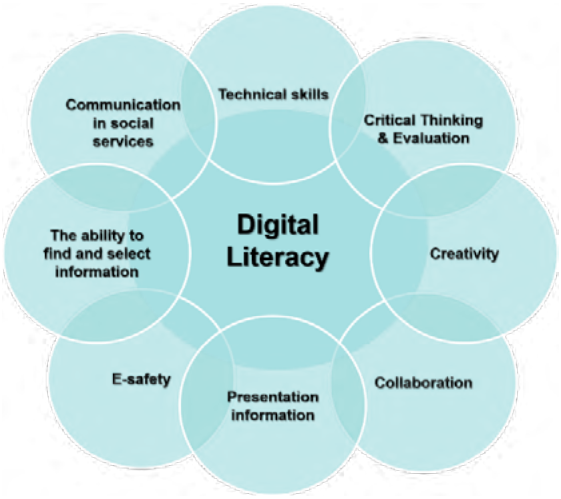

Fig. 1. Characteristics of Digital Literacy

The discipline formation plan was developed based on Table 1. Thus, the sources of information are the feedback of teachers who conducted classes with students about the peculiarities of the organization of the educational process and student surveys. In order to design the survey, theoretical material on the structure and content of digital competence was elaborated, as well as a number of questionnaires used by educational institutions and individual researchers. The table provides a framework of factors around which to develop the learning environment and assessment activities of the students. Factors have also been suggested logically, which may increase students' chances of perceiving the subject environment as an encouraging and supportive approach to problem-based learning.

From this, it becomes clear that the student must have the skills to use digital services at the technical and communication level. That is why it was important to form a discipline based on the needs of computer technology when a student is working on blended learning technology and is engaged in solving various team tasks.

Table 1. Factors more likely to improve digital literacy in ICT discipline

The digital-based learning environment. The following factors are essential to achieving a learning context likely to encourage digital competencies approaches:
1. The discipline has a clear structure.
2. A convenient LMS is used to present the materials.
3. Organization of discipline by BYOD technology (i.e. it is convenient to study using any device).
4. Tasks are created according to Bloom's taxonomy and meet the goals and requirements for blended learning.
5. Students receive a more personalized education.
6. Part of the tasks inclines to group work on the joint project.
7. Course objectives provide for the formation of a personal digital environment.
8. The teaching is flexible and provided with constant teacher support.
9. The problematic tasks to the topics stimulate the development of critical thinking.
10. Maintaining constant feedback after each lesson completion.
Learning activities should:
1. Be creative and experiential.
2. Encourage the study of cloud services and technologies.
3. Improve the quality of Google Docs usage.
4. Ensure effective retrieval, selection and presentation of information from the network.
5. Tackle real-world problems that will echo with the students' experiences.
6. Ensure effective presentation of research findings.
7. Ensure the effective use of social networks for work and study.

In addition, the modern development of information technology has led to the creation of a course based on services and technologies already owned by students and which they can directly use during their studies [13]. Therefore, it was one of the reasons to use BYOD (Bring Your Own Device) technology as technical support of ICT discipline. Having conducted the survey, students in almost the vast majority (98 %) decided that they would work on smartphones.

4 FINDINGS

After the preliminary survey, at the beginning of the semester, students were informed that this subject would be taught and organized differently from other disciplines at the university. We shared the goals of the ICT discipline, the BYOD approach, the concept of blended learning, digital competence. The students realized that the changes had been made for a specific purpose, and met modern requirements for the future specialist. Discussing changes with students was an important first step in engaging them in the course design process, and it was a key criterion for further effective research.

The course was divided into eight topics, with one specific topic for every two weeks. During the semester, students started a joint project, which they defended at the end of the course. The purpose of the team project was to conduct a study of a product (sociological survey, creation of a device, stand, software application, video, etc.) for their professional activities and to explain its advantages and disadvantages over the products of this category.

Theoretical training was carried out in advance, and in the classes, the students performed problematic tasks, discussed unclear moments and intensive practical activities on studying the means of information technology. All topics prompted more attention to the technical components of the services and devices on which they

worked, the development of critical thinking, time management and presentation of the results of the tasks. The contact hours of the student teachers were transferred to the online network, which increased the support of learning twice and eliminated the barrier between the teacher and the student, prompted more questions from the student.
Students received specific assignments and theoretical materials for each topic in LMS Google Apps for Education. Reflection was provided by an entry and exit ticket (expectations and "exit ticket"), which made it possible to shape the expectations of each topic better and improve the tasks of the following issues after the feedback.
Approaches to student learning in 2019 were evaluated to inform the stages of reflection and work out of the research cycle of action. Overall, the activity of 12 groups was analysed before and after the course (Table 2).
The data were collected using an anonymous questionnaire on Google Forms.

Table 2. Elements of the short-answer questionnaire used at the beginning of the study

1.	How long have you been using a personal computer (PC)?
2.	What types of devices do you use?
3.	For what purpose do you use a desktop computer or laptop?
4.	What types of mobile device do you use?
5.	For what purpose do you use mobile devices?
6.	Do you know how to work with LMS?
7.	How did you find out about new digital technologies?
8.	How would you rate your typing skills?
9.	How would you rate your web search skills?
10.	How would you rate your computer literacy skills (ability to use a computer)?

Survey results show that students mainly use laptops and smartphones for social networking, gaming and personal communication. Although the age of students varied from 16 to 18 years, and the use of digital technology was around 8-10 years, this did not affect the deeper purpose of technology for teaching and further professional activity.
The assessment of the subject consisted of a baseline questionnaire (see Table 3) in which students determined the level of ownership of different technologies and competences after completing the course. This task was designed to require students to reflect on their learning and therefore, to encourage a more technical approach to learning.

Table 3. Questionnaire elements used to investigate changes in the use of digital technologies

1.	Can you create and update web pages?
2.	Can you record and edit digital videos?
3.	Do you feel competent in using digital learning resources?
4.	Do you use social networking services?
5.	Is it easy for you to learn something by reading it on your computer screen?
6.	Do you have any mobile apps that you use to learn languages?
7.	Do you use Google Docs services?
8.	Please indicate your frequency of use for each of the following means by placing the pointer in the appropriate box: "Very often", "Frequently", "Sometimes", "Rarely", or "Never".
9.	What do you think are the factors that influence the use of digital technology?

All tasks involved assessing students' level of competence. The digital proficiency level results (see Table 4) showed a statistically significant change in the educational approaches used by students before and after the course.

Table 4. Analysis of digital literacy levels before and after completing the ICT course

Digital literacy tools	Before taking the course				After passing the course			
	Engineering		Humanities		Engineering		Humanities	
	Number of students (General 60)	%	Number of students (General 60)	%	Number of students (General 60)	%	Number of students (General 60)	%
Usage of mobile applications for training	29	41	20	38	60	86	46	77
Usage LMS	23	33	16	27	61	87	55	92
Usage of cloud services for training	39	56	27	45	55	79	39	65
Search for information on the network	58	83	41	68	63	90	51	85
Presentation of digital business results (presentations, infographics, video content)	37	53	34	57	62	89	48	80

5 DISCUSSION

The purpose of the study was to increase the proportion of students who have ICT using digital literacy techniques. It was partially achieved after the end of the experiment. More than 56 % (n = 72) of students were classified as using several digital literacy increase techniques.

Overall, there is a significant increase in digital literacy among first-year students. It can be concluded that the implementation of the ICT course focuses on digital competence, which are:

1. Motivates students to learn through the constant inclusion and ease of use of different technological environments.
2. It covers students of different learning and thinking styles.
3. Allows students to create their unique products that reflect their personality and learning needs.
4. Provides more efficient search, selection and management of media to build your content.
5. Allows students to more creatively and efficiently share their achievements with the environment.
6. Will enable students to explore technological environments, which inevitably enhances the job skills that employers seek in today's professionals.

On the other hand, studies have shown that further increasing the proportion of students who will effectively use digital literacy tools in higher education is not an easy task. Achieving a significant effect takes time and some changes to the learning environment.

Although the proportion of students who have improved their digital literacy levels has increased since the beginning of the semester, some issues should be addressed.

An essential aspect of the study was the qualitative comparison of digital skills and the speed of mastering new information competencies between engineering students and

humanities students. The study found that engineering students were better able to learn certain services and technologies that they did not possess before studying the discipline. Critical thinking and constructiveness, consistency of problem-solving among these students were more noticeable in the course of practical work.
An important aspect of the study was the qualitative comparison of digital skills and the speed of mastering new information competencies between engineering students and humanities students. The study found that engineering students were better able to learn certain services and technologies that they did not possess before studying the discipline. Critical thinking and constructiveness, consistency of problem-solving among these students were more noticeable in the course of practical work.
Students' perceptions of overload were an important factor in the relative underperformance of the experiment. Most of the respondents in the survey noted that there were many tasks and sometimes the technical complexity of some of them reduced the level of motivation to study.
More than 55 % of students indicated problems with time to complete tasks. The problem with the perception of time to teach ICT may well be the load on other subjects that students have studied. Engineering students typically have about six to eight courses per semester (18 weeks), with up to three assignments per topic. By gradually reducing the load on the subject, you will be able to solve the problem.

6 CONCLUSION AND ACKNOWLEDGMENTS

The research conducted here indicates that the prospect of further teaching ICT based on digital literacy can be an impulse to erase the boundaries between different disciplines and specialities. First, only high-quality, in-depth approaches to learning can lead to high-quality higher education outcomes. Second, large-scale interventions may be resource-intensive and may not always be optimal for the student.
The results of the study showed a statistically significant improvement in the proportion of students who have improved their digital skills, and indicate the need to continue implementing the ICT course in all areas of undergraduate training. A broader context involves changing the meaning of teaching other subjects and studying at the university. Impacting different components of the broader context is likely to be challenging. Changes in the level of the course and the context of study will need to influence the teachers of other subjects of the course.
The variability in the study of the percentage of students using digital competency tools (see Table 4) emphasizes the need for continued action research. Research is needed to confirm that the 2019 results were not one-offs but a consequence of changing learning approaches. Additional research is also planned, which will include in-depth interviews that explore students' perceptions of their use of ICT skills in their further professional and educational activities. Only by acquiring such knowledge, we will be able to hope for improvement of learning environments and the better development of students in society.

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SHORT PAPERS

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TEMPERAL TRENDS IN TEXTBOOK TRACKING DATA

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ABSTRACT

Time is an underdeveloped aspect of textbook reading analytics. We used the Living Textbook, a concept-based digital textbook, to collect tracking data during an introductory MSc course. In this paper, we compare first-time concept visits versus subsequent concept visits, the time when these concept visits occur and the duration of the concept visits. With the collected information, we want to optimize the length and order of the learning pathways. Although many concept visits are generated close to the exam at the end of the course, these are often re-visits, indicating a review before the exam rather than procrastination.

1 INTRODUCTION

Learning analytics are widely used in higher education to monitor and predict student success [3,4], and for learning design purposes [2]. This paper explores the use of textbook tracking data, collected during an introductory course on Geographic Information Science (GIS). The digital textbook, called the Living Textbook (LTB), is a combination of a concept map and a wiki with additional learning functionalities, including sequential learning. Learning pathways are chains of concepts addressing a single learning objective that lead students through the reading assignments. They are comparable with a chapter in a regular book.

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The learning behaviour of students is often non-linear and does not always follow the pre-defined learning pathways due to difference in learning experience and learning styles [7]. The same user can show different reading behaviour during different phases of the course. Ogata et al. [6] distinguish “preview” and “review” behaviour, indicating reading before or after the teaching moment. Junco and Clem [4] developed an engagement index to measure the interaction of students with textbooks, including the number of days and sessions the student was active. The temporal dimension of learning analytics has been underexposed, according to [5]. This study adds the perspective of time into the analysis of tracking data. The question addressed in this paper is: “Which temporal patterns can we find in students’ use of the Living Textbook, and how can we use this information to optimize the learning pathways?”

2 METHODOLOGY

2.1 First time versus revisits and their timing and duration

The temporal aspect of tracking data subdivides into several essential elements: How many times the student visits the concept (1) when a student visits a concept (2), and how long the concept is visited (3). We distinguish two types of concept visits: first-time visits and consecutive visits. The assumption is that study behaviour differs between first-time and subsequent visits. The second element is the moment in time during the course when the subsequent visit takes place. A subsequent visit may be a review during exam preparation, especially when these revisits take place shortly before the exam. If a subsequent visit takes place close to the teaching moment and this teaching moment is at the beginning of the course, students may still be familiarizing themselves with the tool and effectively the learning during the first visit is small.

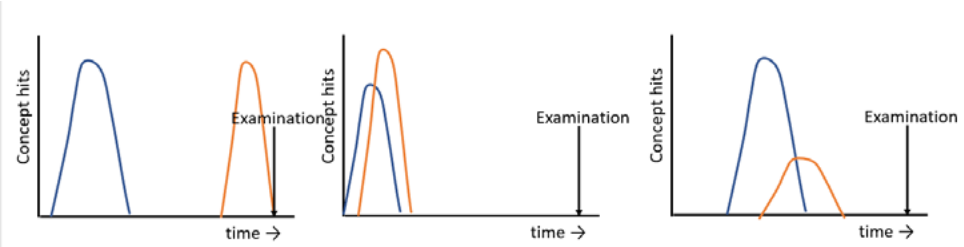

Figure 1 (left) first time visits (blue) and subsequent visits (orange) to prepare for the exam (middle) first time visits (familiarize with tool) and subsequent study visits (orange) (right) first time visits (blue) and restudy visits (orange)

The duration of the concept visit may also give an indication of the type of visit. When this concept visit is relatively short this browsing behaviour could be associated with learning how to operate the tool, or moving through a learning pathway to reach another concept for review. When the duration of the concept visit is long, this can be associated with actual study time. We analyse at three different levels of aggregation: the course, the learning pathway and the concept. For the course level, we analyse all concept visits made by students, for learning pathways

we analyse visits made by students to concepts that are included in a learning pathway, and at the concept level, we analyse visits of students for a given concept. A combination of a first-time visit at the moment of teaching with a review before the exam leads to a bimodal distribution of the concept visits over time. We check for bimodality via the coefficient of bimodality and the skewness of the distribution [1]. The bimodality coefficient was calculated using the R package Modes. The bimodality coefficient has a range of zero to one where a value greater than 0.56 suggests bimodality.

2.2 Tracking data

The 103 students from a 3-week face-to-face introductory course on GIS were tracked after they provided permission to do so. Before the course, all students followed an instruction session introducing them to the LTB. Besides the LTB, students had access to a pdf version of a traditional textbook with the same content. Before the start of the course, teachers defined fourteen learning pathways - each of these learning pathways covered reading materials that correspond to approximately one day of education. Length of the learning pathways varied between 5 – 14 concepts with a mean of 9.7 concepts per learning pathway.

3 RESULTS

3.1 Temporal trends on Course level

Figure 2 shows the number of concept visits per day. The number of visits stabilises at around 200 concept visits a day, but after September 18th, we see a strong increase leading to 1600 concept visits on September 22nd, the day before the exam. Around 50% of the total number of concept visits is generated in the last four days of the course. Our students seem to show a large tendency towards “last-minute study behaviour”. However, from this graph, it is not possible to see if these concept visits were generated by revisiting students or by new students.

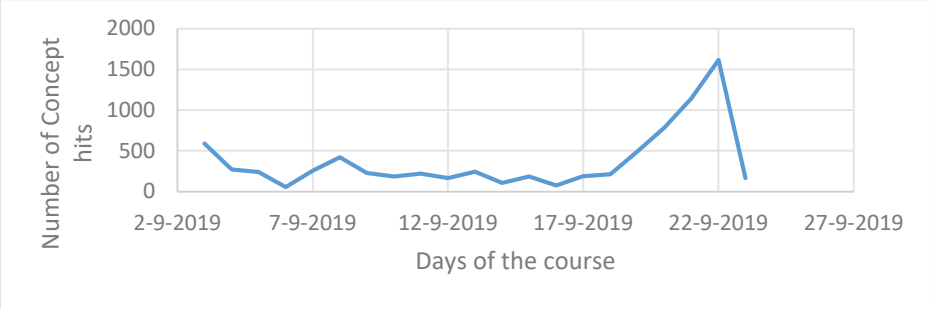

Figure 2 Number of students using the Living Textbook per day of the course

3.2 Temporal trends at learning pathway level

When we analyse the concept visits per learning pathway instead of at course level, we see that student visits per learning pathway are bimodal showing a peak at the time of lecturing and a peak at the end of the course (preparation for the exam). The

bimodality coefficient ranges from 0.668 - 0.896, indicating bimodality for all learning pathways. To analyse the difference between first-time and subsequent visits, we can look at the total number of visits. We seem to generate many subsequent visits (Figure 3 - blue) later in the course. This means that many students review the materials again in the days before the exam. When we compare a learning pathway scheduled early in the course (Figure 3 – path 8) with learning pathways scheduled later in the course (Figure 3 – path 138), we see a gradual shift in the distribution of new users in time. For a learning pathway scheduled later in the course (138), we see that the number of new users during the last days of the course is considerably larger. The time during the course when a learning pathway is scheduled seems to have a large impact on the timing of the concept visits.

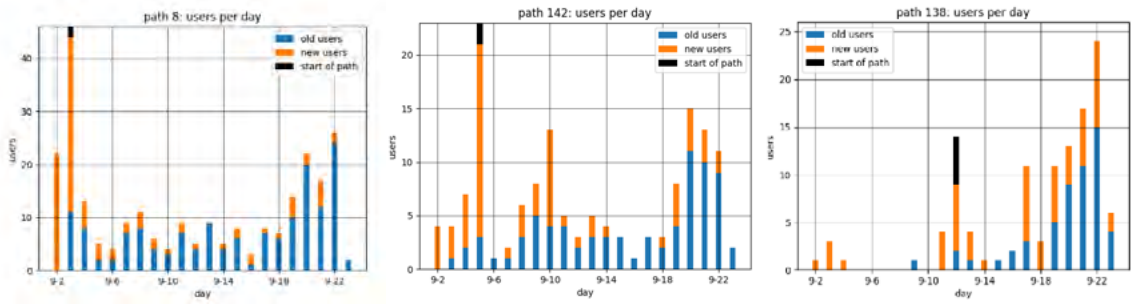

Figure 3 First time visits versus re-visits per learning pathway

3.3 Time per concept

We compare the median time spent per concept per learning pathway with the average time spent, for both new visitors and re-visitors (Figure 4).
When we evaluate the median time spent for learning pathway 8 by first-time visitors, the results are very stable. Most time is spent on the first concept; the mean duration of a first-time concept visit of all other concepts is stable at about 1 minute (60 seconds). This pattern changes in subsequent visits. Concepts earlier in the learning pathway (to the left of the graph) get more attention compared to concepts later in the learning pathway (right of the graph). When we compare this to the average time spent, we see more variation between the duration of the concept visits. Concepts two and three seem to be most studied by first time users, and by subsequent users.

4 SUMMARY AND ACKNOWLEDGMENTS

The total number of visits per day of the course is a very misleading number to base conclusions on. We see large peaks before the exam, but many of these concept visits were re-visits by students that earlier studied these concepts. The later a learning pathway is scheduled in the course, the more first-time concept visits are generated close to the exam. For early teaching, there is enough time to review the materials. Teachers should take this into account when designing their courses. The same applies to the order of concepts in the learning pathways. The earlier a concept is positioned in this learning pathway, the longer the time spent by students

in studying these topics, especially for subsequent visits. Further analysis can help to determine the preferred length of the learning pathways.

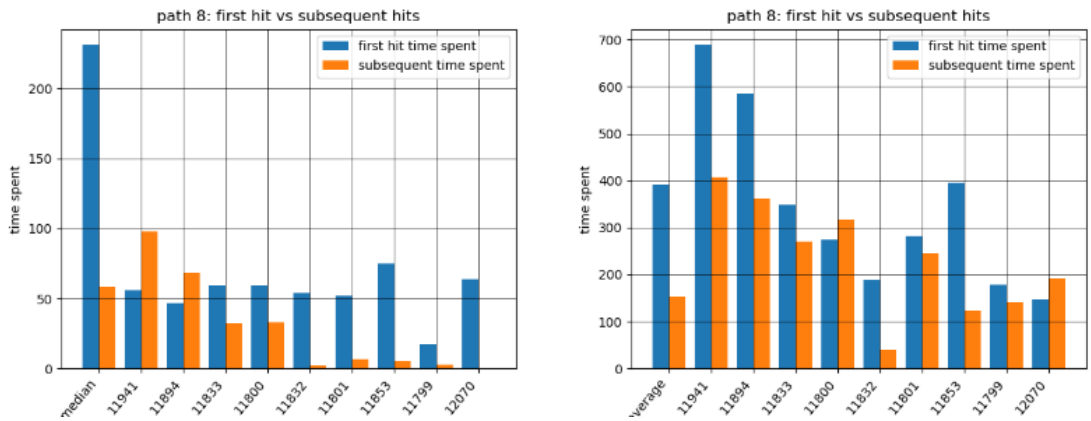

Figure 4 Example of the number of first time versus revisits – learning path with the number of visits (left) median time spent in seconds (middle) and the average time spent in seconds (right)

This research was made possible via a contribution from 4TU and by students that allowed us to track their navigation behaviour.

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PREPARING FOR UNIVERSITY SUCCES: UNIVERSITY COLLABORATION WITH SECONDARY SCHOOLS FOR IMPROVING SCHOOLSTUDENT'S CAREERS, TEACHERS PROFESSIONALISATION AND CURRICULUM DEVELOPMENT

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Conference Key Areas*: Engineering in Schools, improving visibility of engineering disciplines; Engineering curriculum design, challenge based, education, maker projects, use of professional tools*
Keywords*: University collaboration with schools, school careers and study choices, improving secondary school curriculum and teacher professionalization.*

ABSTRACT

In our symposium we discuss 20 years of Dutch practice about the cooperation between universities and secondary schools in preparing students for successful studying. Though the increasing numbers are worth to mention and clarify, not all problems have been solved. As the main values, we state that a good cooperation between schools and universities in educational programs stimulates the study success rates in the universities. Due to better preparation, teacher professionalization and attention for quality of enrolment the study success is increasing. But in practice, there is a lot to discuss about content, organisation, ownership and long term investments. In our symposium we will address three kind of perspectives on these problems: the governmental / state level, the university level and the school level. Representatives of the Ministry of Education, universities and school boards will elaborate their problems, plans and actions for improvement on these three levels. We will show interesting successes in qualitative and quantitative pictures, but also a lot of questions left for further research, policy and practical actions. The symposium will be organized around information about these three perspectives and audience participation by Q&A's and cases.

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We will focus on the practices of two Technical Universities and their school networks: TU Delft and TU Twente. TU Delft has a network of 59 participating schools, TU Twente has 26 schools,. A yearly amount of about 5.000 students and 450 teachers of secondary schools involved in the educationals preparation programs. Both the universities and the schools are proud on the cooperation within these networks: they contribute in ownership and actions with workforce of experts and teachers and with cash money.

1 INTRODUCTION

1.1 Context

How can we better connect secondary school curriculum and university research themes to prepare secondary school students for university? How do we strengthen collaboration between school teachers and university experts especially in the science & technology field? And how can we develop this school-university-networks in a sustainable way?
This symposium is focused on pre-university educational programs for secondary school students as preparation for successful studying in universities. The cooperation between university and schools supports school careers and study choices through focusing on the educational connection, teacher professionalization and curriculum development in the STEM-fields. After years of national policies on strengthening STEM-education our school/university-network has learned much about development and maintenance of cooperation and organization: e.g., physic teachers together with university experts developing lessons and instructions, lab experiments on quantum physics for use by secondary schools. Secondary school teacher are being empowered by their participation in curriculum teams. Also, this unique situation offers university students the opportunity to work in our pre-university programs and schools.

1.2 Problem analysis

Helping and supporting young students with the transition from secondary school to universities in combination with strengthening study success rates in higher education is a comprehensive challenge. The last 20 years national and institutional policy has addressed these issues as main topics. A lot of practices have been appeared, with good and less good examples. Unfortunately, systematic research on causal effects of interventions and factor is still missing. Therefore, it is good to stress and explain the educational importance of systematic practices linked on vision and theory, policy matters, and other practices.
Our symposium will focus on the issue of cooperation within regional networks of universities and schools for secondary education. The rational for this cooperation is supporting young students in their school careers by three kind of activities: content driven experiences for school students, curriculum development with teachers and experts and teacher professionalization. Yearly, we welcome each about 6.000 school students in our Pre-U programs for different kind of structural education

activities like masterclasses, workshops, lab-experiments as well as event-wise activities like challenges, school camps and showcase experiments. Where the structural education driven activities have a regional approach, the event-wise activities have both a regional and national reach.
In the symposium we will present and discuss three perspectives: 1. the rational, the vision and the EU/Dutch national policy [1] and institutional policy that has been a strong support for developments and practices; 2. The daily practice and organization of the structural education programs and the event-wise activities; 3. A school leader will discuss the experiences of the network partner schools with our cooperation, the experiences of school students and teachers and the relevance of network building as well as adjusted institutional policy making as a backbone for daily practices.

2 APPROACH: THREE PERSPECTIVES

2.1 Perspective 1. Rational, vision and policy

Since 2002/2003 the EU-policy and Dutch national policy on R&D [2] started to stress the meaning and relevance of STEM-education and STEM-related jobs. In fact, for Dutch situation it was necessary to repair the decline for years in the field of STEM-related subjects in education and labour market. After years of low interest in these subjects by young adults the policy has been focused towards reparation and stimulation of qualitative strong education in these fields. In the period the Nationa Dutch STEM Platform was established to organise the activities at a national level, exchange good practices and monitor the process of all contributors and partners. One of the factors was a better organization of cooperation between secondary and higher education. A lot of universities have chosen to work with a kind of pre-university program. The aim of all these pre-university programs was stimulation of better study program choices by content driven experiences and successively a higher success rate in higher education for individuals, education tracks and institutions. In general, the pre-university programs put together the work of university experts, teachers of secondary schools and students.
In our symposium we will give a short overview of EU/Dutch policy, the institutional policies and organizational implementation questions and conditions since 2003. Also, we give insight into different kinds of visions behind the model of pre-university programs. The vision, rational and policy stimulation are essential conditions to build practices for youth empowerment in their school careers and build a sustainable network of cooperating schools and universities as divided parts of a school system.

2.2 Perspective 2. Pre-Universities, Teacher professionalisation & Schools Network: dialy practices and research orientation

The second part of the symposium will show and discuss the university point of view for organizing a pre-university program in a network with secondary schools. As a centre of knowledge, the university has to play a role at the content level but also

often as the initiator of a lot of organizational processes. Besides the organization of education programs like workshops, masterclasses and honours programs for secondary school students it is worthwhile to collect data, monitor and evaluate.
The TU Delft and University of Twente has a lot of experience with a large responsibility for students in (co)creating educational programs together with school teachers [3]. Therefore, in our context it was a logical choice to bring in the fresh and bright experiences of a large student group, besides a small expert staff. E.g., the practice of Pre-U at the University of Twente has been running for about 10 years. Therefore, we are able to present and discuss some interesting research data about participation, reach, quality issues and appreciation by schools and students. Causal relations between pre-university interventions and effects on study choice and success rate are difficult to investigate, but we can show some interesting findings in correlational predictions. Examples are found in the data about the relation between chosen school subjects, study choices and study success rate in the first year of higher education. Another example can be found in the data about hours of learning investment / participation, study choices and study career.
Based on the practice, the daily experiences and joy of students and schools, and the evaluation data, we draw the conclusion it is worthwhile to share the practices, experiences, tops & tips with other school practitioners. Further, we will discuss our findings and practices with earlier published research by Michels & Eijkelhof (2018) [4] and Vulperhorst c.s. (2017) [5].

2.3 Perspective 3. View point and experiences of a school leader

The third part of the symposium is dealing with the viewpoint of secondary schools participating in programs for pre-university students and teacher professionalization. Two secondary school leaders as members of our partner schools will tell and discuss the daily organization within a school, the questions a school is dealing with, how to learn within her own school and from other schools in the network of partner schools and the university. Central viewpoint will be the relevance of pre-university programs in the school path of young adults, but also in the contribution to curriculum, teacher professionalization and school development. The cooperation with a university and other schools have brought to school an open mind set with an external orientation. Further, the structured way of feedback on student performance to the school has an impact on curriculum and education discussions within the school.

The school leaders will discuss the advantages and challenges of being a partner in a joint network of schools and universities. The discussion will give many insights in school internal arguments and decisions before starting, developing and participating in these networks.

3 RESULTS

3.1 Tables

The National Dutch STEM Platform has adequate information on their website about numbers in the STEM-fields [6]. Table 1 shows the national numbers of secondary school students who are choosing STEM-oriented school profiles [6]. These profiles provide access to academic technical and science study programs. From 2003 up to 2018 we see a strong increase in the STEM-fields. The main part of this progress is due to girls: they are changing their choices towards the STEM-fields over the years.

Table 1. National increase STEM-profiles in schools (numbers of students)

Year	NT-profile	NG-profile	NT&NG-profile	Total
2003	23.153	39.807	9.378	72.338
2010	31.337	46.378	27.163	104.878
2018	44.577	62.255	18.955	125.787

Following the increasing numbers of school students choosing for STEM-profiles we expect an increasing amount of student influx in STEM study programs. Table 2 shows the data since 2005 up to 2018 [6]. We see an increase indeed, but not proportionally. This is called the STEM-leak in the system. A lot of girls are choosing study programs outside the STEM-fields.

Table 2. National increase STEM-influx Dutch universities (numbers of students)

Year	Science	Engineering & Technology	Agriculture & Technology	Total
2005	4.852	6.950	1.429	13.231
2010	7.255	8.960	2.631	18.846
2018	11.626	15.717	4.128	31.471

At the SEFI-Conference 2020 we will examine these numbers in more details.

Both TU Delft and TU Twente have organized regional networks with secondary schools. The TU Delft network contains 59 schools; the Twente network 26 schools. For teachers the school/university networks organize meetings for instruction, curriculum development and teacher professionalisation. In 2019 the network of the TU Delft organized for secondary school teacher over 70 meetings divided over all science topics in schools. In total more than 450 teachers participated in 2019. Physics, Chemistry and Nature, Life & Technology were very popular topics. The network of Twente is smaller and shows a proportional amount of activities for school teachers. Chemistry teacher professionalization was very popular in 2019.
Also, at the SEFI-Conference 2020 we will examine these numbers in more details.

The same school-university networks deliver programs for secondary school students from year 1 up to year 6. Yearly, large numbers of school students participate in educational programs like masterclasses, workshops and skills-labs. In practice, target groups which are involved are defined as very smart kids but also regular school kids who can get some support. The programs are mostly running on-campus. Numbers vary between 15 pupils to 150 per program. Besides the educational programs, there are also daily events organized which often contain. The yearly basis is about 5.000-6.000 school students that will be reached and participate.

4 CONCLUSION AND DISCUSSION

The Dutch national policy on stimulation of the STEM education in secondary and higher education started in 1998. Now, 20 years later, we can show some good practices and increasing numbers but also a lot of questions too. Founding networks between universities and schools is very fruitful for a good preparation for study success and worthwhile to explain at the SEFI Conference 2020.

Starting with the student's educational success in higher education in the STEM-fields it is obvious there is interest for the universities to start a good cooperation with secondary schools. The main interest is the quality of the yearly enrollments. The quality of the enrollment is related to the quality of the educational programs in secondary schools. And this quality is dependent on the quality of the teachers. Therefore, it is worthwhile to cooperate as networks in teacher training and professionalization programs. The teacher approach has to be integrated with the network activities for the school students.
Beside the quantitative and qualitative information and practices we will discuss problems of content approaches, policy issues and organisational implementation. Examples of big questions are the long term support of the Ministry of Education, the acceptance in the institutional policy and the link between experts and school teachers. There is also a challenge in the coherence with outreach agenda and societal impact of research groups.
Our contribution to the SEFI-conference 2020 will be a symposium with three perspectives from policy to organization of the networks and examples from the daily practices. The symposium will be organized around information about these three perspectives and audience participation by Q&A's and cases.

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DEVELOPING SENSOR TECHNOLOGY INNOVATIONS WITH BUSINESS POTENTIAL TOGETHER WITH STUDENTS: LET'S RETURN TO THE MASTER-APPRENTICE APPROACH

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Conference Key Areas: *Interdisciplinary engineering education, Engineering curriculum design*
Keywords: *Critical thinking, master-apprentice approach, complex problems, dealing with uncertaincy*

ABSTRACT

ID3AS is a programme in the field of sensor technology to stimulate innovation and network creation in the Eems Dollard Region (EDR), the most northern region along the Dutch-German border. The ID3AS-programme provided an opportunity for over 80 students with different backgrounds to participate on a scala of real world challenges. Real world learning environments like these are becoming increasingly popular in education, so it is important that we know how to organise the participation of students and tutors effectively.
However, in ID3AS it proved challenging to realise a fruitful learning experience for the students, while simultaneously adding real value to the projects. The difficulty stems from the fact that both students and tutors struggle with the inherent unclarity of innovation projects, while at the same time industry partners need actual results. We think that the currently prevailing approach of the student learning by discovery, with the tutor in the role of process supervisor, is suboptimal in these conditions. Based on our experiences we propose to have students join a consortium as an 'apprentice' to a 'master'. The master, being a tutor from either university or company, should be comfortable with leading by example in an uncertain environment where both learning outcomes and concrete results are expected. We present several examples where this approach worked and give the outline of an experiment we plan to conduct on this topic.

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1 INTRODUCTION

ID3AS[2] is a multi-year research and development programme in the field of sensor technology. The aim of the programme is to create a network of companies and knowledge institutions in the EDR, developing viable innovations ultimately resulting in economic activity and employment opportunities.
From various application domains, such as Care, Agro and Logistics, the project team attracted companies with promising ideas in the field of sensor technology. These companies were then supported to form a consortium with other relevant parties such as potential customers, content experts or a party that could bring the idea to the market. German-Dutch cross-border cooperation was a mandatory requirement of the funder. All in all, our work has led to more than 25 consortia and projects between German leadpartner Hochschule Osnabrück/Lingen and the Dutch Hanze University of Applied Sciences Groningen (HUAS). The data in this paper are based on the 10 projects on the Dutch side of the border managed by HUAS.

Although our main obligation to the funders of the programme was to create succesful innovations together with companies, our mission as a UAS motivated us to have as many students and lecturer-researchers participate in the projects as possible. In that sense ID3AS acted as a living lab/Innovation Workplace (IWP). In an IWP, partners from research, education and professional practice collaborate on complex issues whose solution requires the co-creation of knowledge in a way that transcends traditional boundaries of structures, sectors, disciplines and forms of learning [1]. The concept of IWPs is becoming increasingly popular with Dutch UASs as a way to prepare students for the complex interdisciplinary challenges of the future. HUAS, for example, has the ambition that all students participate in an IWP at least once during their studies.

To ensure long term viability of the IWP concept, it is crucial that all parties involved benefit from participating in an IWP. For this paper we will look specifically at the way students and their tutors are involved. We believe that the current way of involving students in our consortia can be improved. Our goal is to maximize the students' contribution to the project, provided that the students have a good learning experience. This learning experience encompasses both subject-specific competences and general competences such as being able to deal with uncertainties and complexity in collaboration with others. The way in which student work and supervision are organised plays an important role in this.

[2] www.ID3AS.org

2 EVALUATION OF STUDENT AND TUTOR INVOLVEMENT IN ID3AS

During its duration, ID3AS facilitated many student assignments, internships and graduations (see Table 1). Students have worked on sensor selection, testing, designing sensor circuits, data analysis, user interface design, business models, legal issues, gamification of a webapplication, building an activity tracker, measuring stress, applying artificial intelligence, etc.
Tutoring of students was typically assigned to a lecturer-researcher. This supervision focused on progress of the project, the groups working process or achieving learning outcomes.

Table 1: Parties involved in ID3AS

Parties involved	Nr
Student groups	>20
Individual graduates	5
Total number of students (Engineering, Business, Law, IT, Communication and Lifesciences)	>80
Lecturer/researcher in the role of tutor	13
Companies	18
Knowledge institutions	6

We have experienced that the current way of working and learning by students and tutors did not function optimally in the ID3AS projects. Characteristic of these projects is the complexity of working across disciplines, multiple interests, intercultural communications, and flexibility based on business potential of the innovations. These are exactly the kind of things we want our students to learn in IWPs, but it proved to be challenging.
Engineering students as well as business students showed frustrations due to preceived vagueness of what is asked of them, evolving requirements and the feeling of having to discover everything on their own. They found it difficult to acquire the extra knowledge required for the problems at hand. They felt overwhelmed and this resulted in lack of commitment and mediocre results.
Unfortunately, the tutors, who can be lecturers and/or researchers, were of limited help to the students. The tutors struggled as well with having to adapt their tasks, working in a interdisciplinary instead of a monodisciplinary setting, the executive role that was required for achieving project results and guiding students in working on flexible and evolving content. Initially lecturer-researchers were hesistant to join the project. When they did join, they stuck to the coaching role instead of providing the students with some much needed ‘scaffolding’ [2].
These difficulties had an effect on the external partners. They were regularly frustrated with students because of lack of progress, low quality results, lack of commitment, not considering alternatives, and not being allowed to change the assignment over time.

As the project progressed, we carried out several ad-hoc ad-hoc interventions to address these challenges and improve the results of students' work (Table 2).

Table 2: Interventions on student/tutor involvement

Nr	Interventions
1.	The approach of trying to create an assignment was changed into asking lecturers and students what they thought they could contribute (self-efficacy).
2.	Company staff and students started working in a shared office at HUAS for two days a week (shared workspace). The climate in the office used was to be controlled by the system under development. (Smart Indoor Climate project).
3.	Company actively organized lectures and expert training to bring students up to speed when knowledge was lacking (Smart Ship Management).
4.	Lecturers actively joining the student work as foreman (Smart Marine Aquaponics, Voicemint).
5.	Organising a project startup of two days for company and students under the guidance of AI-experts from HUAS (Smart Indoor Climate).
6.	Providing expert guidance to business students on how to do real world business modeling to guide the decisions of consortia, instead of the one 'trick' they had learned so far.
7.	Involving the tutoring lecturers and students as much as possible in the different project meetings so they can see the big picture.

These interventions had a positive effect on the earlier mentioned challenges. Students learned formally and informally from their more experienced colleagues and project members from their or another field of expertise. Students started to display more ownership for the project result and developed more courage to question assumptions or an approach. This lead to a more valuable contribution of students to the project as well as a more valuable learning experience; students were more succesful in applying their knowledge and skills in an interdisciplinary environment.

Something similar applies to the lecturer. Lecturer-researchers were more actively involved in the project team, working with students and professionals in the field. They took more responsibility for the project result, invested time in keeping their knowledge up to date, and experienced the value of their expertise within the breadth of competencies needed for successful innovations. This is reciprocal teaching and reciprocal learning, which contributes to a more valuable educational guidance of students, now and in the future.

This leads us to the following assumption: in the complex projects typically found in IWPs, a more hands-on involvement of lecturer-researchers and a different way of guiding students (master-apprentice, agile) will give students a better learning experience while also bringing about better project results.

3 DISCUSSION

Basically these findings match with what is already known from theory, for instance Dochy's model of High Impact Learning [3], principles of agile development [4], and scaffolding of interdisciplinairy learning [2]. Still, we expect many UASs to struggle with similar issues and if we are to make the concept of IWPs succesful we shall need to improve.

The main issue with the master-apprentice approach is scalability. It is unlikely that this approach can be adopted for every project in the short term. Still, not all is lost. First of all, we noticed an improvement with the lecturers over the years. By gaining experience in the projects, lectures gain confidence. The lecturers who enjoy this kind of work can take on more and reach economy of scale. Secondly, when the companies experience improved results, they are likely to be more willing to make the financial contribution necessary to make this approach more affordable. And in the end, we feel that if we are running these kinds of projects anyway, we'd better do it in the best possible way.

4 FURTHER RESEARCH

In further research, colleagues at HUAS plan to test our assumptions in a controlled setting of one research group. Lecturer and researchers and students will form four small teams to work on a research question from an external customer. The lecturer/researcher will not just be supervising the students but will work side by side with the students. Students are to be made owner of a part of this project and have contact to the customer. Expectations and experiences from all parties will be gathered before, during and after the project. The results will provide more insight into the effects of this way of collaborating.

Our ambition is to further develop this experiment into a vibrant research environment where students and lecturers collaborate with the professional field on complex problems. The first experiment along these lines started in Februari 2020. Due to the corona pandemic, the experiment was severly limited. It is hoped that the experiment can restart in September.

5 ACKNOWLEDGMENTS

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CREATING A FLEXIBLE PEDAGOGICAL QUALIFICATION PROGRAM AT A GERMAN UNIVERSITY OF TECHNOLOGY

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Conference Key Areas: *Future engineering skills and talent management, HE & Business & Career support*
Keywords: *Pedagogical Qualification Program, Evaluation, Engineering Pedagogy, Research-Based Learning*

ABSTRACT

A high quality engineering education builds, amongst other things on pedagogically competent teachers. Thus, to strategically qualify all involved teachers at a university is desirable; but in Germany it is still voluntary. Recently, a German University of Technology established an obligatory pedagogical qualification program for all research assistants employed under universitys' budget. This short paper highlights the program design, the first evaluation and present partipants' reaction. A 60 hour, maximum two year lasting program that is flexible, individualized, needs-based and hands-on with foci on "Higher Education & Engineering Pedagogy" and "Research-Based Learning" was designed. Intending to empower participants' pedagogical competencies, the program consists of an initial consultation, workshops, complementary elements and a final event. First of all, it is questioned how participants react to the program. Therefore, registrations were investigated and quantitative surveys carried out before and after three months of running the program. Data was analyzed using descriptive statistics. First, results indicate positive participants' reaction to the program while individual pathways play an important role, such as key program characteristics. Secondly, results indicate that pedagogical competence acquisition takes place early in the program and is important for participant reaction but is limited for now. Thirdly, besides the program

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design, participants attitudes and supervisors support are relevant factors for participant reaction and proper learning. It is planned to detect the participants' reaction, learning and future teaching prospective after completing the program using a mixed-method approach, to develop the program further and to find university wide solutions besides the program itself.

1 INTRODUCTION

High-impact educational practices need to meet enabling conditions and must overcome multiple obstacles (e.g. [1], [2], [3]). Among others, developing academics' pedagogical competence is key in implementing modern engineering education as shown exemplary at a German University of Technology (see [4]). In Germany however, pedagogical training still relies mostly on single voluntary workshops. Only exceptionally, training programs are obligatory for special target groups. These programs face limited participants' acceptance (see [5]). Importantly, participants' acceptance of a program has a decisive influence on participants' learning success within it; and this in turn on their prospective intentions in teaching practice (see [6]). To address this, a German University of Technology recently introduced a more flexible, obligatory pedagogical qualification program called I³ProTeachING [7]. This short paper gives brief insights into the pilot phase of this program by firstly emphasizing the program design and evaluation and secondly, highlighting how participants react to this flexible program at the very beginning of the program.

2 METHODOLOGY

To ensure and enhance high quality education, the Executive Committee of a German University of Technology initiated a qualification program on interdisciplinary and innovative teaching in engineering for all research assistants employed under the university's budget. It commissioned its center for teaching and learning to implement a training in cooperation with the university's graduate academy. Based on earlier experiences (see [4], [5]), it was required to design a flexible, 60 hour program within max. two years and variable enrolement date.

2.1 Designing a pedagogical program

It is aimed that participants are able to discuss pedagogical principles, apply methods and media in teaching, develop their teaching personality, present a teaching related product and network on the subject of teaching across institutes after completing the program. Therefore, participants choose one competence line: (1) "Higher Pedagogy & Engineering Education" (HP/ EE) according to [8] or (2) "Research-Based Learning" (RBL) according to [9] and [10]. Participants inform themselves at an information event, they arrange an initial individual conversation, select core and accompanying workshops from a quite broad catalogue, conduct three complementary elements, namely reflection (each person alone), peer visit (2 persons) and teaching project (up to 3 persons), and join a final event. In the final event, participants present and discuss their teaching project product (e.g. a poster) with the university's community and are rewarded with the certificates which are

acknowledged in the graduate academy's phd supplement. Within the program, participants make use of *Mahara* as e-portfolio and collaboration platform. In total, they experience a variety of teaching and learning methods and media within the program. The participants' learning outcomes are assessed during the program by peers and educational developers and after completing the program by the participants themselves in an online survey. Educational developers mentor the participants in almost all program components. Participants compile their program based on their interests and needs. In summary, it was aimed to offer an individualized and hands-on program that allows flexibility in content and time and orientate on participants' desires and university's goals.

2.2 Evaluating the pedagogical program

To start evaluating the program in the first implementation phase, it was focussed on how participants react to the program. The evaluation was designed according to the first level of evaluating training programs [6]. One assumption was made here: The program design has to be flexible to create a positive participant reaction. Registrations were investigated, one self-designed online questionnaire was conducted prior to the program (n=8 of 37) and a second after three months (n=15 of 31, with only 4 RBL participants). Descriptive statistical analyses were conducted. At this time, interviews have not yet been conducted.

3 RESULTS

3.1 Participants' reaction to the program – program design aspects

As mentioned in the questionnaire before the program started (n=8), respondents find the content and time related flexibility very important (see Fig. 1). Remarkably prior to the start, program characteristics like orientation towards the real needs of teachers and hands-on characteristics (e.g. concrete tips and pedagogical methods in teaching practice) or the scientific basis of the program (e.g. pedagogical principles and theoretical background) were seen as very important or important, too. After three months, most persons valued the individual program compilation as important for themselves (see Fig. 2).

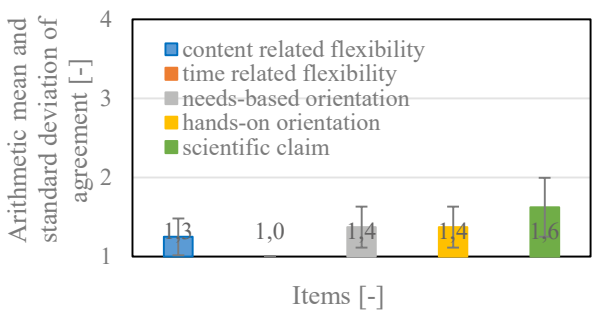

Fig. 1 Agreement on importance of program characteristics, therein, 1…totally agree and 4…totally disagree, arithmetic mean and standard deviation are shown, questionnaire prior to the program start (n=8)

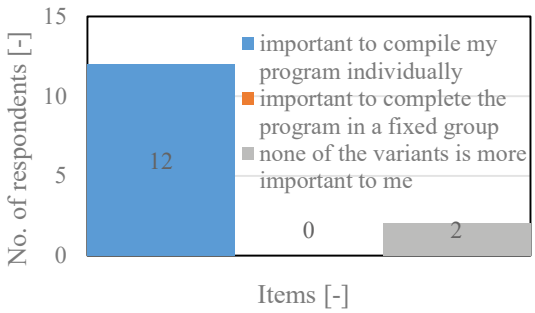

Fig. 2 Number of responses on importance of flexibility, questionnaire three months after program start (n=14)

This is reflected by participants' registrations and their perception of some program characteristic after three months: Firstly, most persons (31 of 37) registered to start the program directly. Both competence lines experienced similar registration numbers (HP/ EE: 13 persons; RBL: 17; one person was undecided). Besides the initial workshop (joined by 14 participants in each competence line), most RBL participants (n=14) directly selected one core workshop with a central topic namely developing RBL, while HP/ EE participants selected four core workshops on various pedagogical topics (supervising & assessing written work, designing assessment, explaining & asking understandable; n varied between 1 and 4 persons). Almost all participants conducted initial conversations and many participated in workshops. Secondly, in the questionnaire after three months (n=15), respondents perceived their selected "competence line" to be interesting or very interesting (12 of 13 persons) and to be relevant or very relevant for their teaching (11 of 12 persons). Free text responses indicate that participants selected workshops because they met their interests in improving courses, they adressed daily teaching challenges or enabled them to exchange experiences on a specific topic. Interestingly, after three months, respondents perceive the program as relevant or very relevant for their recent research (7 of 14 persons) and prospective career (9 of 14 persons). However, after three months four respondents deemed the program as slightly hindering due to the time it involved adding to the already busy daily workload. To shed light on participant reaction, it is focussed in the next chapter on participants' learning at the beginning of the program, their attitude prior to the program and supervisors' support.

3.2 Participants' reaction to the program – participants' learning in the beginning

Prior to the start of the program, respondents (n=8) perceive all intended program learning outcomes on higher education pedagogy as important or very important. Interestingly, after three months, participants stated similar learning goals like enhancing teaching quality or exchanging with others. Furthermore, HE/ EE respondents assess to have good fundamental pedagogical competencies, despite handling teaching challenges (n=9). On the contrary, RBL respondents presume to have moderate RBL competencies (n=4), despite higher presumed competencies in brainstorming ideas for implementing research-based learning. Respondents experienced the initial conversation, workshops and *Mahara* as helpful to achieve their goals at the beginning of their program.

3.3 Participants' reaction to the program – aspects besides the program design

Firstly, responses (n = 8) before the start of the program point to a positive participants' teaching attitude. Exemplary, respondents perceived developing teaching quality at this university as fundamentally important, engaging in teaching as joyful and a pedagogical qualification and their personal participation as rather important or rather appropriate. Secondly, evaluation results indicate that participants perceive supervisors' support as important and that they feel supported

by their supervisors. Concretely, prior to the program start (n=8), respondents mentioned proactive support by their supervisors as important. After three months, 12 of 13 respondents stated they felt their supervisors' tolerance, support or explicit encouragement regarding their program participation.

4 CONCLUSION AND OUTLOOK

A flexible, obligatory pedagogical qualification program for research assistants at a German University of Technology was designed and evaluated. It should be strongly highlighted that the meaning of the results presented here needs cautious interpretation and is not conclusive due to relative low response numbers in questionnaires and since we did not yet conduct interviews. However, based on the results presented here, predominantly positive respondents' program reaction before starting and at the beginning of conducting it was detected. It is argued here that an obligatory pedagogical program should offer individual pathways among other key program characteristics in order to create positive participants' reaction. Moreover, it is claimed that quick learning is important for a positive participants' reaction. However, complex pedagogical competence achievement is envisaged to develop over time in several program components. Additionally, it is desired that a program approach includes interaction with supervisors, breathing space in the busy daily workschedule and the use of challenges in teaching practice as a starting point for academics' qualifications and implementation of high-impact educational practice for advancing students' engineering competencies. Importantly, although some findings might indicate to be in-line with results of earlier studies (see [4], [5]), several aspects remain open in this small concept study. Hence, further attempts will be made (1) to further evaluate the program on the levels of reaction, learning and behavior after participants' program completion using both quantitative (questionnaires) as well as qualitative methods (interviews), (2) to develop the program correspondingly further and strengthen thereby the connection to a strong competence development framework for research assistants and (3) to act strategically on dimensions that frame the pedagogical program such as teaching culture and resources.

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SIMULATION AS AN EDUCATIONAL TOOL IN THE ENGINEERING CURRICULUM

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ABSTRACT

Simulation has become increasingly important in professional engineering over the last few decades. In undergraduate education, simulation tools are often taught in advanced-level classes to equip students to use them in industry. However, simulation is not widely used as a pedagogical tool itself within engineering education. This paper examines the current evidence base for simulation as an educational tool and discusses the output of a student internship at Ansys Granta focusing on this topic. An undergraduate student intern from the University of Cambridge evaluated the potential use of Ansys Discovery Live software to support a first-year undergraduate engineering curriculum. Worked examples across the fields of structures, mechanics and fluids were tackled, and Discovery Live was used both to attempt to replicate these examples and to extend them. This qualitative study found that, for the examples where Discovery Live was found able to support the curriculum, i.e. able to accurately simulate the problems tackled, it provided significant benefits to the student. These benefits included visualisation of problems, the ability to tackle more complex systems, interrogation of the assumptions and idealisations inherent in many hand calculations, and the possibility to either supplement or replace physical lab experiments where required. This paper also proposes a cost-benefit approach to evaluate the wider inclusion of simulation tools as teaching tools in undergraduate engineering curricula and consider the trade-off against instructor workload to highlight types of undergraduate engineering teaching where simulation could provide most benefit.

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1 INTRODUCTION

1.1 Current knowledge

Modelling and simulation tools are of increasing interest for undergraduate engineering teaching due to their prevalent usage in both research and industry. There have been a number of individual studies of undergraduate engineering teaching and learning using modelling and simulation tools across the engineering undergraduate curriculum [1,2,3]. Across multiple studies, benefits to student learning outcomes are reported [4] but difficulties include students' perceptions of simulation tools and the steepness of the learning curve to use them effectively.

1.2 Ansys Granta opportunity

Granta Design Ltd, a leader in the field of undergraduate Materials education, was acquired in 2019 by Ansys, Inc, a leader in multiphysics engineering simulation. An opportunity therefore arose for a student internship at Granta evaluating the potential of existing Ansys simulation tools to be used effectively in undergraduate teaching. Discovery Live was chosen as the most suitable tool for this study due to its easy learning curve thanks to its automatic meshing and real-time simulation capabilities.

2 METHODOLOGY

2.1 Overview

The internship was a 12-week project, including company induction during the first week and project reporting in the final two weeks. There were thus approximately nine weeks of simulation work. The intern was given a computer containing a GPU capable of supporting Ansys Discovery Live. The project supervisors did not have any previous knowledge of Discovery Live, or any personal access to the software during the internship. The intern was at the end of his 2nd year in the undergraduate Engineering course at the University of Cambridge, and had not previously used any simulation software either as part of the course or for personal interest. Supervision meetings were weekly, with regular self-reporting required from the intern.

2.2 Goals

The project plan was for the intern to self-learn Discovery Live and use it to tackle a number of analytical engineering problems taken from the 1st and 2nd year material of the University of Cambridge Engineering degree course. The intern was therefore already familiar with the analytical solutions of these problems, but was required to simulate the problems using Discovery Live and to extract answers to the problems from simulation. These simulation results could then be compared to the analytical answers. Initial goals were to complete 8-10 problems of this type across a range of standard mechanical, fluids, thermodynamics and vibration problems, identify problems that could not be simulated in Discovery Live, and create documentation for each successful simulation. Additional goals at the end of the project were to identify where problem sets could be extended or deepened for further learning using the simulations developed. There was also a task to look at 'learning types' (lectures, labs, etc) and suggest where each simulated model could add most value.

3 RESULTS

3.1 Self-learning of Ansys Discovery Live

Having been provided with Discovery Live, the first goal was for the intern to self-learn the software. It was hoped that a typical undergraduate student with no previous experience of simulation tools could teach themselves to use Discovery Live, given its automatic meshing and real-time simulation. This goal was mostly achieved. The student intern was able to grasp the vast majority of tools and capabilities within a week using the software help, online resources and template models available. The only issues that arose were around technical terminology used within Discovery Live which was beyond the understanding of the student but was required for successful simulations – e.g. 'slip symmetry' in fluid dynamics.

3.2 Problems Attempted

A total of ten problems were simulated successfully: four in fluid dynamics, three in structural analysis, and one each in the areas of materials, thermodynamics and modal analysis. A further six problems from the same teaching areas were considered and rejected, some because Discovery Live could not simulate them fully, others because the simulation would be too simple to add any understanding.

An example of the outcomes from one simulation shows the typical scope of work. This structural analysis problem considered a load on a pin-jointed truss as shown in Figure 1, and required use of virtual work and a displacement diagram to solve analytically. Using Discovery Live, a slender truss with rigid joints was simulated, as this was considerably easier than including pin joints and provided an additional learning outcome. The vertical displacement of node C as reported by Discovery Live was within 0.07% of the analytical virtual work solution. The intern was also able to extract vector displacements for each point in the simulation and thus create a 'simulated' displacement diagram as shown in Figure 2.

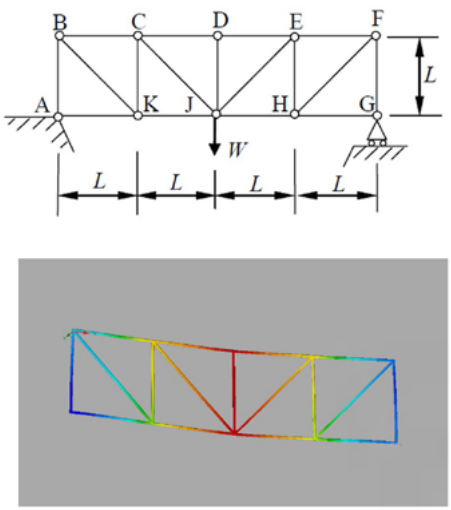


Fig. 1. Analytical problem (above) and Discovery Live simulation highlighting displacement (below)

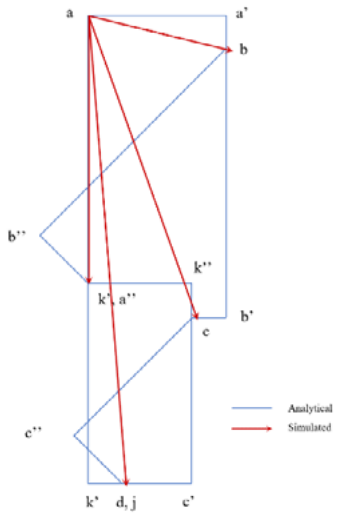


Fig. 2. Overlaid analytical and simulated displacement diagrams, to scale

The student intern also created a short 2-page 'case study' for this problem, with instructions on setting up the simulation, results to be expected and sample plots. The benefits of adding a simulation aspect to this analytical problem were threefold, as reported by the intern and observed by the supervisors: firstly, an animated visualisation of the problem aided intuitive understanding of structural mechanics, deformations and support movement; secondly, the ability to gain solutions which agree with the analytical methods reinforced the understanding of those methods; and thirdly, the process of setting up the simulation problem highlighted assumptions and areas in which the intern's physical understanding of the problem were weaker.

3.3 Additional Learning Outcomes

Across all ten problems that were simulated, the intern reported additional learning points which were not within the scope of the original analytical problems. In some cases these were learning about simulation, as in the case of boundary conditions, but in many cases they concerned real physical aspects of the problem which may be mentioned in introductory engineering courses but are usually assumed to be unimportant when solving these problems analytically. These included mixing lengths for fluid dynamics problems, spring masses in modal vibration problems, and various assumptions within classical beam theory such as slenderness of beams.

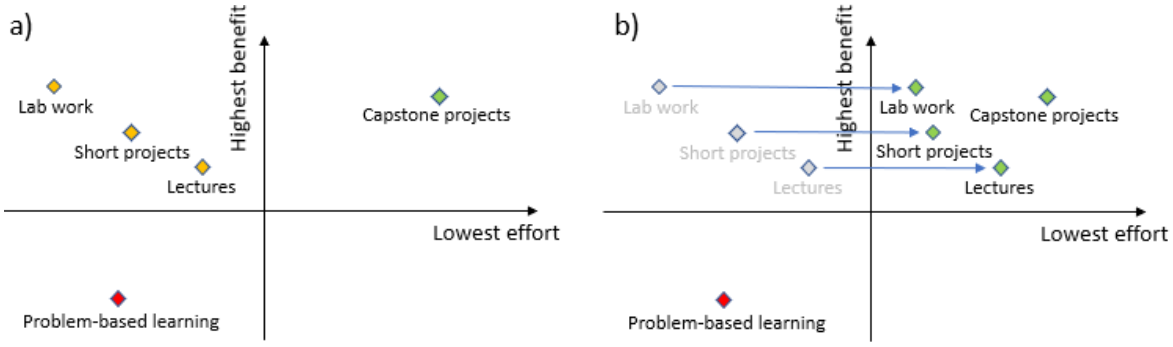
3.4 Project Limitations

Although the student chosen for this internship was representative of a standard 2nd year undergraduate engineer, there are factors which are likely to have given him an advantage over the average student using these tools for the first time. Most importantly, the intern had regular access to supervisors who, while not familiar with Discovery Live, had previous exposure to other simulation tools and were able to assist in identifying setup errors or erroneous assumptions in his simulations. The intern also likely had higher motivation to learn simulation since this was a paid internship rather than an extra thing to learn within the undergraduate curriculum.

3.5 Cost/Benefit Approach to Including Simulation in Curricula

The scope of this project was not just to assess the additional learning that could be supported by adding simulation to undergraduate teaching; it was also to assess the practical challenges of requiring students to use a simulation tool such as Discovery Live in introductory courses. This study was not aiming to quantitatively assess the learning benefits to the intern or, by extension, the potential for benefit to the wider student body. However, through the intern's self-reporting of his learning, the study qualitatively highlighted benefits in the areas of visualisation, understanding of assumptions and the ability to study complex problems. Other studies have attempted more rigorous measurement of student outcomes following the use of simulation or modelling [4], which similarly to this study report benefits to the students when they are adequately supported by well-designed documentation or active supervision. In order to decide whether to include the use of simulation tools in a curriculum, the educator effort required to support students in this way must be weighed against the benefits that students will gain.

At the end of this project, the intern was asked to reflect on which types of teaching he felt the extended problem set would best fit. He personally felt the use of simple visualisations in lectures or more detailed 'virtual lab' projects in labs were areas of introductory engineering teaching where significant benefit could be gained. Reflecting on these and other types of teaching, we propose a simple cost-benefit analysis to conceptualise the trade-off between teaching effort and student benefit, as visualised in Figure 3(a). The points on this chart are placed qualitatively, based on the benefits reported by the intern and the supervisors' understanding of the likely workload required to properly introduce simulation to each type of teaching. The top right quadrant of this figure is the area in which the educator effort required is reasonable to achieve the benefits. As can be seen, with no available resources for the educator to draw on, we believe the only teaching type which fits in this quadrant is capstone design projects, where a significant learning curve is acceptable and students can use software with which their supervisors are unfamiliar. However, Figure 3(b) shows a hypothetical situation in which other types of teaching become tractable in terms of educator effort required. Arrows represent the creation of resources which educators can draw on to reduce individual effort required, thus making it reasonable to consider introducing simulation into these types of teaching.



Figs. 3(a) and 3(b). Illustration of a possible cost-benefit analysis to assess educator effort required to introduce simulation into a teaching type (x-axis) vs. reported benefit to students of doing so (y-axis).

Examples of such resources could range from simple pre-made animations to aid visualisation in lectures, to lab experiment resources with full simulation models and worked guidance for demonstrators. We believe that the creation of these resources, and their availability within the wider academic community, are key to enabling the use of simulation and modelling tools within undergraduate engineering education.

4 SUMMARY AND ACKNOWLEDGMENTS

This project shows that it is possible for an undergraduate engineering student to gain significant benefits from the addition of simulation to a traditional problem set across multiple areas of fundamental engineering teaching. However, it is important to identify the areas where greatest benefit can be gained, and how students using simulation can best be supported without significantly increasing teaching workload.

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PROMOTING METACOGNITION SKILLS IN STATICS THROUGH SELF-EXPLANATION: A PRELIMINARY STUDY

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Conference Key Areas: *Future engineering skills and talent management, Engineering in Schools, Physics in the engineering curriculum.*
Keywords: *Statics; Metacognition; Self-Explanation, Problem-solving, Worked-Example*

ABSTRACT

This study explores how the use of self-explanation activities in Statics may support student development of metacognition skills. Metacognition can help students in Statics to be more aware of their thinking process for problem-solving. Self-explaining is a knowledge-building activity which may promote student metacognitive skills. This initial study explored the characteristics of student self-explanations of a given worked-example in the context of Statics equilibrium. Three students with different academic performances participated in an activity where they wrote their self-explanations for each step in the worked-example. The preliminary results demonstrate that students used different approaches to self-explain the worked-example, some approaches including instances of metaconitive processes, and how such differences may be related to their academic performance.

1 INTRODUCTION

Statics is considered a fundamental engineering course that is difficult to understand for students. This particularity tends to have a negative impact on their performance in this subject and, therefore, in later courses which build on the proper understanding of Statics [1-3]. Promoting the development of students' cognitive and metacognitive skills can strengthen their problem-solving skills, and allow students to reason better about the physics and geometry concepts presented in the classroom. The goal of this research process is to explore the characteristics of student self-explanations of a given worked-example, and the relationship between students' approaches to self-explain and their problem-solving skills in the context of Statics equilibrium. Investigations suggest that there is a connection between students' prior knowledge and the kind of explanations they write [4].

This paper is organized as follows: (i) Section 2 explores the relationship between metacognition, self-regulation, and self-explanation activities; (ii) in Section 3 we describe the methodology concerning this investigation; (iii) Section 4 presents the results of this preliminary study, and (iv) the last section shows the conclusion and future work.

2 METACOGNITION, SELF-REGULATION, PHYSICS MISCONCEPTIONS AND SELF-EXPLANATIONS

Emphasizing the importance of controlling and regulating our own learning process is one of the tasks that educational researchers have long suggested in different areas of knowledge. Student academic performance could be considerably improved if they learn to regulate their learning process [5]. Metacognition refers to the knowledge we build regarding our cognitive processes and products, and the way in which we constantly monitor, control and organize these processes to achieve a desired end [6]. Cognitive regulation, also called self-regulation, is the metacognitive skill that allows students to regulate their learning process, managing the resources and strategies available to guarantee the success of a given task [7-8]. Teaching students to learn how to monitor their understanding may be helpful for developing their problem solving skills [9].

Self-explaining is a knowledge-building activity directed by the students who generate explanations for themselves. Students start from a worked-example and expert's solution to a problem – and should go beyond the provided information to create these explanations [13]. The self-explanations support student learning by: (1) the students identify and complete gaps in their understanding and missing information within the example; and (2) the students revise and repair their mental models by contrasting new information to what they already know [13]. The self-explanation activities demand students to be more aware of their learning process by monitoring their understanding of the worked-example. Monitoring the learning process itself is considered a metacognitive skill among those necessary for the students to self-regulate their learning [14]. This preliminary study explores the characteristics of student self-explanations of worked-examples in the context of Statics equilibrium, and the relationship of students' explanations and their performance in the course.

Student misconceptions about Physics affect student performance in Statics. These misconceptions are often represented in mistakes such as not considering all the forces between bodies in contact, not separating the system under study into sections, trigonometry mistakes, spatial perception and Newton's 3th law [10-12]. Hence, we may find some of these misconceptions in student self-explanations of Statics examples.

3 METHODOLOGY

3.1 Design, Participants and Data collection

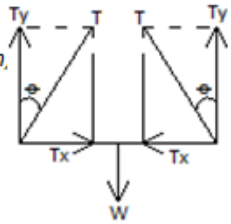
This study used a multiple case-study crossover design [15]. Three students enrolled in a Statics course at a private mid-size university were invited to participate in this study. These students obtained different academic performance during the course (Student A: High, Student B: Medium; Student C: Low). The data included students' written self-explanation of a worked-example of Statics equilibrium, which was divided into five steps following the Statics problem-solving model [16]. Figure 1 depicts two of the problem-solving steps in the worked-example. The unit of analysis

is each student individually. Due to space constraints the complete worked-example is not presented in this paper.

Student explanations were analysed using thematic analysis, a method employed to identify, analyse and report themes within collected information [17]. Every case was divided into categories, which were then classified in themes that would characterize the different approaches in students' self-explanations. For instance, one of the characteristics that are often present in a high-quality explanation includes the appropriate use of principles or laws and the proper application of conceptual knowledge [18-19]. The student explanations that connected to Statics principles and included a detailed explanation of the example were categorized as fine-grained explanations (FN).

2. Modeling

2.1 *To calculate stress "T" in each arm, it is necessary to understand that in order to stay fixed in the indicated position, the weight of the gymnast has to be compensated by the stresses of the ropes that hold the rings. From the free-body diagram on the right side, we calculate the vertical components of the stress "T" in each arm.*



3. Governing equations:

By symmetry, the magnitude of the stresses for both arms is equal. The rectangular component "Ty" is obtained by multiplying the stress "T" with the cosine of the angle formed with the adjacent leg.

$$\sum Fy = 2T.Cos\theta - mg = 0$$

Fig.1. Fragments of worked-example activity: Step 2 (Modelling) describes how to find one of the unknowns by explaining what happens and its effects on the solution. Step 3 (Governing Equations) shows to the student how and why equations are structured for computing results.

Another important characteristic of high-quality explanations is the use of inferences [20-21]. These inferences (IN) are the result of students using background knowledge and clues from the example to fill the gaps in the information provided in the worked-example. To identify student metacognitive skills, we used categories such as planning (PL) and monitoring (MN). Planning statements are often used to identify the conditions under which certain procedures can be useful, while monitoring statements let them assess their understanding of the example. Also, if a student writes an own solution (OW) to a worked-example step, this is also considered an instance of a metacognitive process.

In addition to the self-explanation activity, students engaged in problem solving before and after the activity. Their responses to these problem solving activities were also qualitatively analysed. The categories derived from such process allow us to identify whether they included: effective use of trigonometric functions (TF), drawing free body diagram (FBD), and the right elaboration of equilibrium equations (EE).

4 RESULTS

Student C's self-explanation represents what we considered a poor quality self-explanation. Table 1 shows some Student C's explanations. Student C used a *limited approach* to self-explain the worked-example. Which means a poor quality

self-explanation that includes incorrect and incomplete explanations, paraphrasing and omitting valuable information from the example text. Common factors through his self-explanation.

Table 1. Extract of Student C's self-explanation, their comparison against worked example text and characteristics

Student C's sentences	Worked example text	Characteristic
"…*We will take into account tensions in arms are similar to be under the same conditions*…"	There is symmetry in the body (previously assumed), that is, the right side is subjected to the same conditions as the left side.	Paraphrasing
"As described in point 1."	"…Subsequently, it will be necessary to know the angle of the resulting 'R' given by the weight of the body, in order to calculate the resulting force acting on the shoulder…"	Omitting valuable information

Student B was enrolled in the course for a second time and got better grades than Student C did. This student demonstrated understanding of the domain knowledge in Statics, going beyond the information provided (IN). Student B used her background knowledge or principles to describe each section. Table 2 shows an example of Student B's explanation. Student B provided a higher quality self-explanation compared to Student C.

Table 2. Extract of Student B's self-explanation and their characteristics

Student B's sentence	Characteristics
"Mainly, exercise poses a gymnast in balance whereby we can use the equations that always have been used $\sum Fx = 0$, $\sum Fy = 0$ *...In order to calculate stresses, which undoubtedly must have the same magnitude and enlargement angle, since they're in the same conditions…".*	Background knowledge
	Mentioned a fundamental principle of Statics equilibrium
	More detailed explanation

Finally, Student A, who showed a high academic performance, demonstrated some instances of metacognitive skills in her explanations. A high-quality self-explanation depicts a clear conceptual understanding of the example and the ability to apply it in a different context (Transfer) [5]. Table 3 shows some aparts from Student A's explanation and their categories we assigned to it.

Table 3. Extract of Student A's self-explanation and their characteristics

Student A's sentences	Characteristics
"…The sum of the 'Y' components of both stresses are equal to the weight, and for static equilibrium we separate it and we get the stress…"	Planning
"…Since the arm is embedded in the shoulder there will be an "X, Y" reaction plus a Moment…"	Inference
"…The length of the arm is useless because there isn't sum of Moments…"	Monitoring

Student A described the plan (PL) to calculate the unknowns. Also, the inferences made by her let us identify metacognitive skills inside of her written work. This student inferred (IN) a particular condition called embedded beam and its effects. Additionally, a monitoring statement (MN) were evidenced when she pointed out a given data point that was unnecessary.

As we just described, three students with different performances in Statics used different approaches to self-explain a given worked-example. Table 4 compares the differences in students' approaches to self-explain. Evidently, academic performance plays an important role in the quality of student self-explanations

Table 1. Comparative chart.

	Quality Self-Explanations		***Metacognition Skills***			***Concepts***		
						Math	***Statics***	
Student (performance)	***FN***	***IN***	***PL***	***MN***	***OW***	***TF***	***FBD***	***EE***
A (high)	+	+	+	+	−	+	+	+
B (mid)	−	+	−	−	−	+	+	+
C (low)	−	−	−	−	−	−	−	+

5 CONCLUSIONS AND FUTURE WORK

This preliminary study showed the different approaches students used to self-explain a worked-example, and how academic performance may be related to the quality of their explanations. These results are supported by previous research, which demonstrates that students with better academic performance go beyond to the given information [9], monitor their understanding [22] and write a greater number of self-explanations [23]. There are two main limitations for this study: the sample size (only three students) and a completed worked-example. Using incomplete or incorrect worked-examples may prompt student metacognitive processes to either complete or correct the problem solving process. Future work will compare the use of incomplete and incorrect worked-examples on the development of student metacognitive skills in a classroom environment.

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THINKING WITH CARE - GENDER, DIVERSITY AND ENVIRONMENTAL RESPONSIBILITY IN ENGINEERING EDUCATION

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Conference Key Areas: *Sustainability and ethics, Diversity and inclusiveness*
Keywords: *Gender, Diversity, Sustainability, Engineering Education*

ABSTRACT

The paper presents an ongoing study of the one-semester compulsive module Blue Engineering at Technical University Berlin (TU Berlin), which is designed to raise social and environmental awareness and responsibility of engineering students. Homepage research, ethnographic observation and a qualitative analysis of 17 learning journals written by students of the module are used to explore (1) how the gender and diversity unit was perceived by students and (2) if being taught social and environmental responsibility helped engineering students to develop a caring attitude towards marginalised human and more-than-humans.

INTRODUCTION

1.1 Gender in the engineering classroom

Gender plays a central role in engineering. As an essential dimension it structures the field of students, researchers and employees in engineering subjects such as civil engineering, electrical engineering and information technology as well as computer science. The figures for new students show for Germany that while in 2018 51.3% of students that started to study were women* [1] only 26,3% of women* were among new students in the first semester of an engineering degree [2]. Various studies show that the under-representation of women in engineering contributes to a discriminatory professional culture which leads to high drop-outs, worse working contracts and early career endings for women in technology driven subjects [3].

1.2 Gender and Diversity Skills as Key Qualifications in a Changing World

Processes of technology development and technology design are deeply gendered. Therefore a fundamental change in the professional culture is needed in order to eliminate discrimination and marginalisation due to gender and other social inequality categories [4]. Even though the implementation of gender and diversity issues within engineering education is still in the beginning [5], social and environmental responsibility of engineers are coming already into focus due to fast technological and ecological changes of our world. Diversity and inclusivity are becoming increasingly important for engineering sciences due to the fact that technical artifacts more and more are required to be planned with regard to the ressources needed, applicability, climate justice and social justice. Also large international organisations like the American Society for Engineering Education (ASEE) and the European Society for

Engineering Education (SEFI) claim that gender and diversity issues need to be reflected in engineering practices and curricula [6].

1.3. Posthumanist Caring as a Responsible Attitute Towards the World

Working towards diversity, equity and inclusion has a long history in feminism. In its academic forms such as women and gender studies, teaching gender has also been in a way to teach – figuratively spoken – to care for marginalised others. Feminist researchers in science and technology claim that it is important to reflect gender and diversity not only in the classroom but as entangled with processes of science and technology making[7]. New materialism and the posthumanist approach point out the significance of matter and humans entanglement with more-than-humans such as animals, plants or technical artifacts. Thinking with care is in the following understood with María Puig de la Bellacasa as an engagement with a responsible attitude towards the world. In her speculative exploration of care Bellacasa developes a feminist and posthumanist understanding which takes into account „that in times binding technosciences with naturecultures, the livelihoods and fates of so many kinds and entitites on this planet are unavoidably entangled“ [8]. To respect that entanglement of human and more-than-humans can be seen as a basic condition for responsible engineering in a changing world.

2 METHODOLOGY

2.1 *Blue Engineering* as a Way of Teaching Care

In the following, brief insights into Technical University Berlins' module *Blue Engineering* are given. Since 2011 *Blue Engineering* is located at the Department of Engineering of Machine Systems. It is offered as a 6-ECTS compulsory elective module in the courses mechanical engineering, information technology in mechanical engineering, transport, sustainable management and industrial engineering. The module's central objective is to raise students' awareness of their social *and* environmental responsibility. On average, 80 students attend the four-hour module every semester that entails a range of units on social and environmental issues such as the critical encounter of the idea as technology as problem-solving, productionist worldview or the paradigm of constant growing. Regularly a unit on gender and diversity-issues is offered which consists on talk of a gender expert, an introduction on gender-sensitive language, a game that helps students to reflect on diverse postioning in society and a final discussion. Module's assessment takes the form of a portfolio examination and, in addition to an implementation and development of a *Blue Engineering* learning unit, requires the submission of a learning journal, which the students conduct over the entire teaching period. The keeping of a learning journal is understood as an important part of the individual learning process and is seen as having an enormous impact on students capability to reflect on the complex topics. Therefore students are asked to deliberate every learning-unit while answering questions that are given to them to stimulate a reflection on the given issue and their connection to the field of engineering. Also, they are allowed to experiment in a creative way with the aesthetic form of their reflection [9].

2.2 Research Design

An exploratory study of *Blue Engineering* has been carried out by the author through homepage research, ethnographic observation and an analysis of 26 learning journals of one cohort of students taking part in 2018/2019. Homepage research aimed to get more general information on how the module is structured and what the instruction were to write the learning journals. Ethnographic observation and a content analysis [10] of the learning journals were conducted to get insights into (1) how the gender and diversity unit was perceived by students and (2) if being taught of social and environmental responsibility helped engineering students to engage with a caring attitude.[1] The learning journals were used in this study to gain an overall impression of students' perception of gender and diversity issues and to get insights into their individual thoughts and reflections since educational research shows that learning journals foster skills such as the personal and critical reflection and are therefore useful for promoting metacognitive skills like creativity and originality [11]. Therefore the learning journals were analysed with respect to the following main themes (1) acceptance of the gender and diversity-unit (Was the gender and diversity unit seen as important/interesting? How did students reflect on the content of the gender & diversity unit?), (2) and thinking with care (Did students engage with care as an attitude towards human and more-than—humans? Did students link gender and diversity issues to issues of environmental responsibility?).

2.2 Results

2.2.1 Perception of the gender and diversity-unit

An intial analysis made it clear that not all of the 26 learning journals that were released for research purposes included reflexive content on the gender and diversity unit. Nine learning journals either did not contain an entry for the gender and diversity-unit, or they only included a collection of quotes or images on the subject. The remaining 17 learning journals were written by seven women* and ten men*. They showed that all students found it in general appropriate that a teaching unit on gender and diversity was part of the *Blue Engineering* module. Eleven students, almost two thirds (64.7%), expressed explicitly their strong agreement on issues related to gender, equality and diversity and considered information on these issues to be important in their education in their learning journals. Nevertheless, there were also some varieties in the grade of acceptance and engagement with gender and diversity in the learning journals. Also, the study revealed that students were strongly affected by issues around gender and diversity. Language turned out to be quite emotional. There were students who passionately expressed their gratitude over a gender and diversity unit in their engineering education. It was striking that students seemed to have more trouble to integrate gender and diversity issues into their mindsets than environmental issues. For example some students expressed that they found gender and diversity issues very important while simultaneously showed reluctance to the gender and diversity unit. For instance, one student considered the presentation of the topic too superficial and preferred instead to deepen his/her* knowledge of the relationship between technology and gender & diversity. Another student accepted that a change in language practices had to be carried out with regard to the representation of different

[1] Learning journals were handed in for research on a voluntary basis.

genders, but also was hesitating to do so by him/herselves*. For example, the student was worried that it could be too complicated to use gender- sensitive language or that by representing several genders in language, hegemonic gender roles would be re-established. The student wrote: “Isn’t it (gender sensitive language, *sd*) the absolute opposite of the goal (to speak gender-sensitive, *sd*) if I have to identifiy to certain categories again?” (learning journal 5, translation *sd*).

2.2.3 Engaging with Care

Being taught of social and environmental responsibility helped engineering students clearly to focus on different aspects of gender, diversity and environmental responsbility. Learning journals exhibited students‘ engagement with a caring attitude towards human and more-than-humans. For instance, all 26 students showed signs of unsettlement when reflecting on the amount of energy they consumed or their difficulties to avoid plastic. Also, all students claimed in their learning journals in different ways that technology should be used as an opportunity to enhance the world in a more fair and sustainable way and that caring for the world must be the primacy in the development of technology. Several students expressed their gratitude for the *Blue Engineering* module. One student wrote for instance: “I am very happy, that there is such a module that reflect on the need for social aspects of engineering” (learning journal 14, translation *sd*). However, analysis also made visible that students did not link gender and diversity issues to issues of environmental responsibility. Rather, students recognised gender and diversity issues as additive to environmental responsibilities.

3 SUMMARY AND ACKNOWLEDGMENTS

In sum, results indicate that *Blue Engineering*s’ goal, the development of engineers’ social and environmental responsibility, works successfully as an epistemic umbrella that enables students to reorder their knowledge towards gender, diversity and sustainability goals. Learning journals showed that students are motivated to critically engage with a caring attitude towards human and more-than-humans and that they appear to be willing to take over social and environmental responsibility. Findings also point out that while students were in general very interested in the gender and diversity unit their understanding of the issue can still be improved. To make students better understand their key-role as agents of social and environmental justice it would maybe be helpful to teach gender and diversity issues more closely to the overlying epistemic umbrella of social and environmental responsibility possibly intertwined with care toward marginalised humans and more-than human. Also, findings give indications that students possibly would profit from more time to debate and reflect on gender and diversity issues. Entangled with that, learning journals made it visible that it could also be supportive to relate the gender and diversity unit to research of feminist science and technology studies to give students more insights into the close relationship between gender, diversity and technology on a scientific level [12]. The author would like to acknowledge the support of *Blue Engineerings’* staff and students in the production of this work.

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APPRECIATIONS OF TEACHING METHODS ACROSS CULTURES: LESSONS LEARNED FROM INTERNATIONAL STUDENTS

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ABSTRACT

Although cultural diversity of students is inspiring, teachers need to consider the variation in educational and cultural backgrounds as well as the different characters of the students. One strategy can be the application of student-centred learning. However, this may affect students that have been accustomed to different teaching strategies. Therefore, the objective of this paper is to assess the appreciation of international students for different teaching methods.
A survey and a workshop were held to ask students for their experiences with different teaching methods before coming to ITC, their appreciation of student-centred learning, and to determine personal character traits.
We found that differences between nationalities were rather small, although there were some suggestions that there are differences in attitude between individuals from different continents. The workshop revealed that teachers should better explain and justify their teaching methods as students do not always understand the reason why certain teaching methods are chosen. Besides, with a mixed group of cultures, teachers must stay aware that students sometimes prefer to give polite rather than honest indications on their learning.

1. INTRODUCTION

The number of foreign students studying in the Netherlands is increasing [1] and internationalisation of education is an important focus area for many higher education institutions. Arguments for institutions to stimulate internationalisation are, that it

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provides an international context within the classroom, enhancing intercultural awareness, understanding, and acceptance [2]. Although international and cultural diversity of students can be inspiring, it also comes with challenges for teachers. They need to consider the variation in educational and cultural background of the students when designing and implementing education. But often we lack the student's perceptions on teaching and learning [3]. How this is possibly affected by cultural or educational background is hardly studied before. Most studies to date contrasted groups of "home" versus "international" students (*e.g.*, [4], [5]). A logical starting point therefore is inventorying how teaching methods are perceived by a group of students that is highly mixed in terms of nationalities.

To inventorize the experience and appreciation of teaching methods by students, the educational framework suggested by Chi [6] provides a useful tool. This framework proposes three aspects of teaching which are considered to stimulate deep learning in students: (1) Activity of the student with the goal to activate and actively engage learners as much as possible (2) Construction; creating new outputs based on information provided to students and (3) Interaction with others while learning a topic. These three aspects can be used to group various teaching methods in broader groups.

A typical teaching method that links to the first aspect (Activity) of this framework is student centred learning. This approach is adopted by many universities following a Socratic philosophy to give attention to both cognitive skills as well as meta-cognitive skills (i.e. the learning of the learning) and characteristics of students that may foster or impair the learning progress [7]. A concept that reflects this focus well is student centred learning (SCL; [8]). A workable definition for SCL, and that we will use in this study is (from [8]): "*ways of thinking and learning that emphasize student responsibility and activity in learning rather than what the teachers are doing*." This essentially places student responsibility and activity upfront, rather than a strong teacher control or coverage of academic content. However, such control can be hard to handle for students that come from a culture, or an education experience that has not stimulated this responsibility. However, cultural and educational settings are not the only factors that influence the perceptions and abilities of students to handle teaching methods. Also personal character traits can influence this. A convenient way to characterize personal character traits that works across cultures is the framework presented by Ng and Rayner [9]. In this framework, four character traits (Individualists, Fatalists, Hierarchists and Egalitarians) are recognized. People can be a combination of these four traits, but normally one of these four traits dominates.

Therefore, in this study we have inventoried the educational experience and appreciation of different teaching methods of a group of students from a wide variety of countries across the globe. We have asked them to rate different teaching methods using the framework of Chi [6]. Besides we characterized their personal character traits using a situational judgement test (see methods) to find whether either culture or rather

character provides the best explanation for possible differences in appreciation of education.

2. METHODOLOGY

Data was collected in a survey in July 2018 in combination with a subsequent workshop in December 2018 among the student population of the faculty ITC of the University of Twente. This involved 32 different nationalities. Study guides and colleagues of the faculty were consulted to list the teaching methods used at the faculty. These were grouped within the framework by Chi [6] (Table 1).

Table 1: Classification of teaching methods within the framework of Chi [6].

Without constructing and interaction	Something is constructed without interaction	Something is constructed with interaction
1. Classical classroom lectures 2. Reading 3. Recorded classroom lectures enabling repeating content 4. Unsupervised practical - practice content 5. Watching a demonstration 6. Self-tests or quizzes 7. Searching for extra content additional to material offered by the teacher	8. Supervised practical – *Individually* apply 9. Design a conceptual diagram 10. Concept mapping 11. Learning by doing – *individually* 12. Problem-based learning – *Individually* 13. Physically design something 14. Graphically design something	15. You, asking questions to a teacher in class 16. Classroom lectures with high level of interaction 17. One-to-one feedback and discussion with a teacher 18. Internet-based question and answer session (e.g. chat, skype or a forum) 19. Supervised practical – *in a group/acting as a team* apply content 20. Workshop 21. Presenting and explaining content to an audience 22. Learning by doing – *in a group* 23. Problem-based learning – *in a group* 24. Project work in a group 25. Peer review 26. Fieldwork or excursion 27. Interview an expert 28. Internship

2.1 Survey

The first part of the survey contained general questions on the country of origin, gender etc. Then students were asked to rate all teaching methods using a four-point Likert scale. This forced them to make a choice between “appreciate” or “not appreciate”. The options from which the students had to make a choice were:
(1) I did not appreciate this teaching method
(2) I somewhat appreciated this teaching method
(3) I mostly appreciated this teaching method
(4) I highly appreciated this teaching method
(-) Not applicable, I did not experience this method at ITC.
Lastly, a situational judgement test was added which quantified the four character traits (see [9] for further details).

2.2 Analysis

Based on the opinions of the student population as a whole, a ranking was made from the most to the least appreciated teaching method. Cluster analyses were applied to test if students could be grouped based on appreciation of teaching methods or character traits. The k-means cluster analysis in the cluster package in R ([10]), using silhouette to determine the optimal number of clusters was used. In case specific clusters could be found, it was tested whether these clusters could be linked to certain character traits, or nationalities. Whether a student could be classed in any of the four character categories was done following the method by [9]. Because we had quite many students who were the only one with a particular nationality, we also tested these associations at the level of continents. Chi^2 tests we used to test for significance of associations between found clusters and nationalities/characters traits.

3. RESULTS

After data cleaning and removing survey submissions that were not sufficiently filled in, we ended up with a total of 102 valid recordings. This formed the basis for statistical analyses. Where it was possible to use a larger subset of the recorded data, this is indicated. The cleaned up dataset consisted of 32 nationalities that were present in the faculty, of which five nationalities (China, India, Kenya, Ethiopia and Indonesia) formed the largest groups (figure 1). Almost forty percent of the students was females and just over sixty percent males.

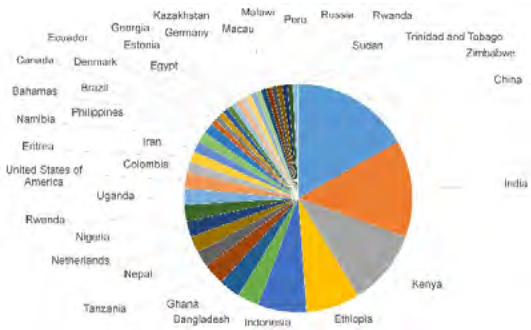

Fig. 1. Origin of students as proportion from the entire student population

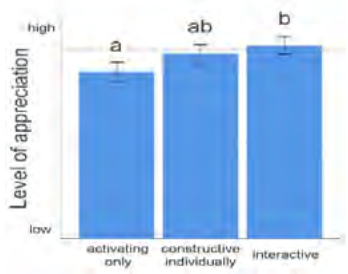

Fig. 2. Relative appreciation of teaching methods within the framework of Chi (2009).

Although student numbers per nationality were too low to draw statistically solid conclusions, we could make some interesting observations about the appreciation of teaching methods and the countries of origin of students. The most striking one is that Ethiopian students scored very consistently the highest appreciation for all teaching methods. In the workshop they hesitantly reacted but confirmed that they always fill in high scores because “they have to be polite”. Some students from Kenya admitted that they also are frequently “polite” because that is how they were brought up. For them the teaching method "peer review” is something they do not feel comfortable with. However, they indicated that with more explanation and by forcing them out of their comfort zone a few times, they had learned over time to do it and their level of appreciation increased.

Within the framework of [6], students seem to have a slightly higher preference for the interactive type of teaching methods (figure 2).

Table 2: associations between clustering of the situational judgement test answers and the characters of students and their nationality, aggregated at the level of continents.

	Cluster					Cluster		
	1	**2**	**3**			**1**	**2**	**3**
Egalitarian	8	24	11		**Africa**	10	25	4
Hierarchist	7	21	7		**Asia**	25	17	4
Individualist	22	0	2		**Europe**	0	1	0
					North-America	1	0	1
					South America	1	2	4

Students in the workshop indicated that sometimes they did not understand why they had to work in groups, why the group had a specific group size and why they were judged based on teamwork. Or, more general, they did not understand why a particular teaching method was chosen for a topic.

In the full survey (n=150) we detected very few fatalists (5) and because these were quite a-typical, we excluded these from further analysis. In the cleaned dataset with only valid references, we had 43 egalitarians, 35 hierarchists and 24 individualists. The cluster analysis revealed that there were no real groups of students that gave very different answers in their appreciation of the different teaching methods. However, clusters could be distinguished based on their answers to the situational judgement test questions to determine their characters. Three clusters could be identified, in which the first cluster mainly linked to individualists, the second cluster linked to both egalitarians and hierarchists, and the third cluster linked mainly to egalitarians (table 2). These associations were significant ($Chi^2 = 42.8$, df = 4, p-value < 0.001). We also created spider diagrams of each character trait (See appendix), and this suggested also that hierarchists and egalitarians had fairly similar characteristics.

When organizing the same three clusters along continents from which students originated we find also a slight but significant ($Chi^2 = 19.5$, df = 8, p-value = 0.012) association (table 2). It suggests that Asian students have a slight tendency towards cluster 1, and African students towards cluster 2. However, it is also immediately clear that one cannot easily place either origins easily into either clusters, as there is a lot of overlap. For the other continents there are too few observations to draw firm conclusions.

Based on these results, we tested if there were any differences in appreciation of teaching methods for these three character types which is shown in Figure 3. Generally there are no large differences between the character groups “egalitarians and hierarchists. However, the individualists seem to have a somewhat different opinion on a few teaching/learning methods like a lower appreciation for “learning by doing in groups” and “online lectures”, “classic face to face teaching” and “demonstrations”.

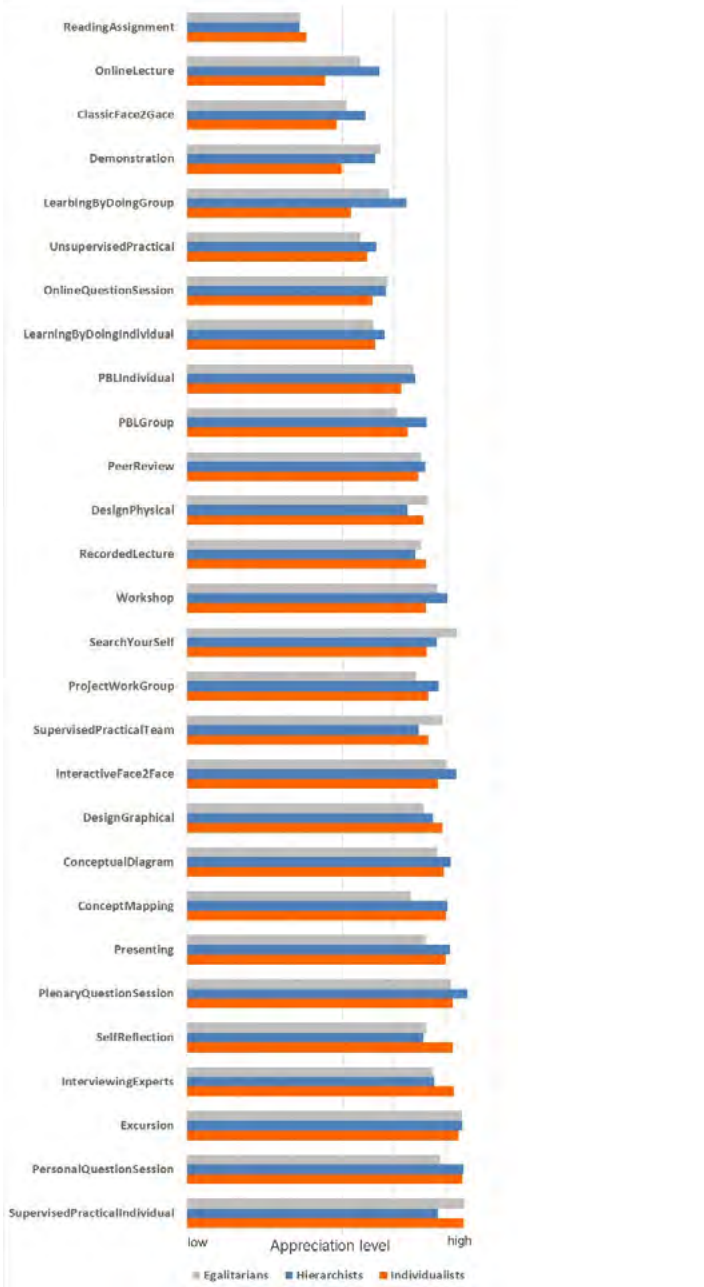

Fig. 3. Appreciation of different teaching methods by students with different characters. N=126.

The main outcomes of the survey and the workshop related to internationalization of education and the application of SCL are: (1) The differences between students with different nationalities are often smaller than the differences between individual students with the same nationality. (2) Both, staff and students will benefit if teachers not only explain the content of a topic and how this is going to be taught, but also take it seriously to explain “WHY” it is taught like this. It helps the students understanding their learning process. And perhaps at second thought, with a fresh look at it, teachers discover that sometimes other methods may be more efficient in their teaching.

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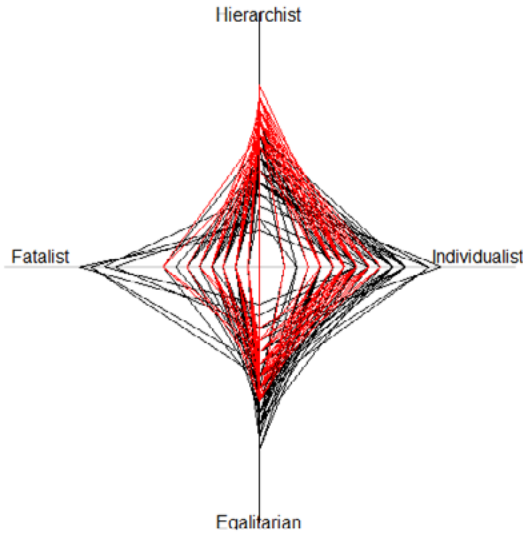
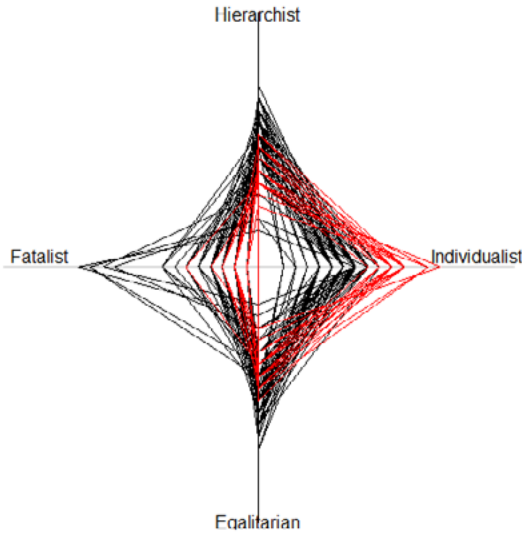
5. APPENDIX

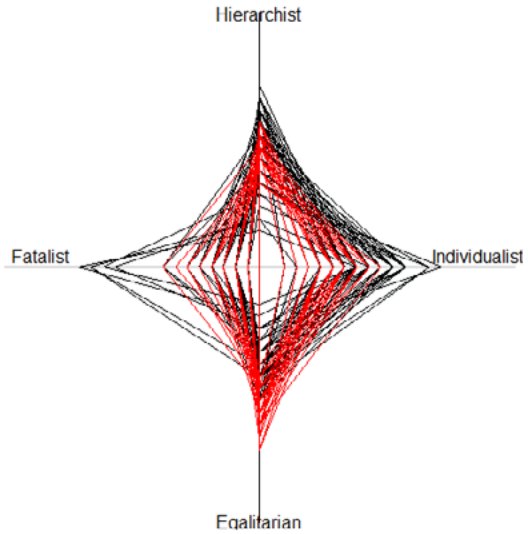
Spider diagrams on Types of students



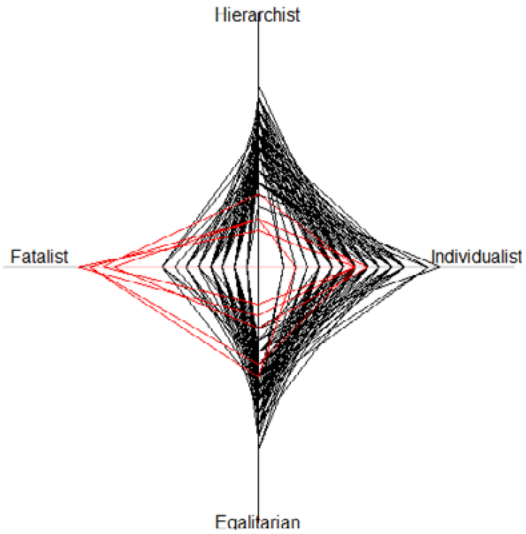
Hierarchists (n=42)



Individualists (n=54)



Egalitarians (n=49)



Fatalists (n=5)

DIGITAL PEER FEEDBACK TO IMPROVE STUDENTS' LEARNING

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Conference Key Areas: *Future engineering skills; Niche & Novel; Engineering curriculum design.*
Keywords: *Peer feedback, large groups, PLN*

ABSTRACT

Feedback can improve the learning process and enhance student achievement[1]. Assessing student work and providing feedback can be done by either teachers, students themselves, or peers. Due to an increasing number of engineering students, teachers lack time to provide students with sufficient feedback. On the other hand, students should acquire skills related to providing and receiving feedback. The implementation of peer feedback could therefore be a fruitful solution. Peer feedback is known as the process in which students evaluate their peer's performance based on pre-determined evaluation criteria[2]. When implementing peer feedback, students can get more, more frequent, and faster feedback as opposed to teacher feedback. Furthermore, peer feedback can enhance learning for both the assessee as the assessor.

In this study, twelve university teachers gathered in a Professional Learning Network to increase their knowledge and thoughtful decision making with regard to implementing digital peer feedback. Student numbers ranged from 20 to 250. Goals for teachers were both related to their own time (e.g. large group, feedback more often) as well as to students' learning (acquiring feedback skills, getting inspired by reviewing each other's work, better understanding of success criteria). Key features of the implementation were clarifying learning intentions and success criteria[3].

Evaluation with teachers and students reveal that implementing peer feedback is a valuable learning experience for students. Teachers especially valued participating in a multidisciplinary PLN, hands-on activities, and sharing experiences with each other.

INTRODUCTION

Peer Feedback

It is well-known that feedback can improve the learning process and enhance student achievement[1]. Assessing student work and providing feedback can be done by either teachers, students themselves, or peers. Due to an increasing number of engineering students, teachers lack time to provide students with sufficient feedback. On the other hand, students should acquire skills related to providing and receiving feedback. The implementation of peer feedback could therefore be a fruitful solution.
Peer feedback is known as the process in which students evaluate their peer's performance based on pre-determined evaluation criteria [2]. When implementing peer feedback, students can get more, more frequent, and faster feedback as opposed to teacher feedback. Furthermore, peer feedback can enhance learning for both the assessee, the student whose work is assessed, as the assessor, the student who assesses the other student's work [4]. Peer feedback can lead to constructive reflection, more time on task, focus on the important elements in the assignment, more insight into success criteria and more responsibility and ownership among students [2].

Besides advantages for students, peer feedback can also be beneficial for teachers. For example, when implementing peer feedback, less and less frequent (written) feedback is required from teachers. Especially with large groups of students, implementing peer feedback can be a feasible solution in order to provide all students with sufficient feedback.

Peer feedback can be provided either on paper, oral or digital. A digital tool can facilitate the process of peer feedback because the digital tool will take away the logistical burden from the teacher. Assigning of assignments and feedback and distribution of the feedback will be done automatically and there are several options that facilitate the feedback process, e.g. anonymous or non-anonymous feedback, group-to-group feedback and feedback on the quality of the feedback. Another advantage for the teacher is that they easily gain insight in the feedback process and the results, and can use this for evaluation purposes.

In the current study, university teachers have been supported in implementing digital peer feedback in their education by joining a professional learning network. In this paper we present the evaluation of this intervention, including (perceived) effects on student learning.

METHODOLOGY

Intervention design

For professional development of university lecturers, a Professional Learning Network (PLN) in which lecturers together develop knowledge, and share insights and experiences, can be effective (e.g. [5]). The main goals of the intervention were to increase lecturers' knowledge with regard to peer feedback, and to support thoughtful decision making with regard to implementing digital peer feedback in their education by sharing experiences and developing good practices together.

The PLN gathered in total four times: two times prior to the quartile in which the lecturers will implement digital peer feedback, one time during the quartile, and once after the quartile. During sessions, theoretical knowledge was presented, experiences were shared, and lecturers developed action plans for implementing peer feedback in their own education, including clarifying learning intentions and success criteria (cf. [3,4]).

Participants

Twelve university lecturers participated in the intervention, of which seven implemented peer feedback in their education in the third quartile of 2019/2020 (February – April). A very diverse group was composed, for example with regard to the number of students in the course (20 to 250), level of the course (from freshman to master), lecturer's experience with peer feedback and teaching discipline.

Lecturers were asked to identify their own reasons for wanting to implement peer feedback. These reasons were both related to their own time (e.g. large group, feedback more often) as well as to students' learning (acquiring feedback skills, getting inspired by reviewing each other's work, better understanding of success criteria). Three out of seven lecturers had (some) prior experience with implementing peer feedback, of which three already had implemented *digital* peer feedback in previous years.

Instruments & data collection

The effects of the intervention will be evaluated at the four levels from Kirkpatrick's model for evaluating training programs (1960) 1 – reaction, participants' satisfaction with regard to the training, 2 – learning, knowledge, skills and attitudes participants obtained during the training, 3 – behavior, how participants changed their practice based on the intervention, 4 – results, (perceived) effects of the implemented changes. See Table 1 for respondents and instruments in order to evaluate the intervention at each level.

		Levels of evaluation				Background
Instrument	Respondents	1.Reaction	2. Learning	3. Behavior	4. Results	characteristics
Questionnaire	Lecturers	X			x	x
Focus group	Lecturers	X	x			
Interview	Lecturers		x	x		
Questionnaire	Trainer	X	x			x
Questionnaire	Students			x	x	

RESULTS

In general, participating teachers appreciated the intervention sessions. Sharing and discussing experiences, overall interaction and exchanging ideas and tips were highly valued, just as hands-on activities. Furthermore, participating teachers indicate the direct link with their own education was very relevant. However, not all participants were able to attend all sessions, there was too much time between the sessions, and two teachers were not teaching during the PLN period. At student level, teachers indicate providing and receiving peer feedback was valuable but also requires time and preparation – for both teachers as well as students. Students indicate that they especially learned a lot from providing feedback, and that providing feedback is an important skill.

CONCLUSIONS & DISCUSSION

The current study was focused on evaluating the usefulness and effects of a PLN a means for teacher professional development for implementing digital peer feedback in their education. Based on the evaluation results, it can be concluded that organizational aspects are crucial aspect for making a PLN successful. Timing of sessions and enabling all participants to attend all sessions and get to know each other, including the prerequisite that all participants are actually teaching over the course of this PLN seems essential for active participation, sharing experiences and being able to experiment in their own education.

The PLN in this study was composed of teachers from various faculties and disciplines, which was referred to as contributing to the learning experience.

At student level, both teachers as well as students indicate that the use of peer feedback is a valuable learning activity.

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DAUGHTERS OF INVENTION: USING DRAMA TO ENGAGE CHILDREN WITH ENGINEERING

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Conference Key Areas: *Topics: Engineering in Schools; Diversity and inclusiveness*
Keywords: *Drama, Engineering, Storytelling, Primary school children*

ABSTRACT

Daughters of Invention is a UK funded drama and engineering project which is developing primary school children's understanding of engineering and STEM subjects. The project targets girls and children from Black, Asian and Minority Ethnic (BAME) backgrounds in areas of high deprivation in Birmingham, UK. The project consists of four interactive and immersive drama and engineering workshops for 240 children aged 9-10, from four inner city primary schools. The workshops are led by experienced drama practitioners from The Play House (UK) and a team of eight engineering students and staff from the University of Birmingham. The project develops the students' outreach and public engagement skills and encourages them to develop their own projects in the future. The workshops use drama and storytelling to provide a dynamic, human story for the children to engage with and give them an impetus to solve the engineering challenges presented to them.

Daughters of Invention was originally created through a Royal Academy of Engineering Ingenious award (UK) and delivered to 240 children in four primary schools in Birmingham (UK) in 2019. The feedback from the first phase was extremely positive and our initial preliminary evaluations demonstrate that the project had a

significant impact. The second phase of the project is currently underway (2020) and at the end of this phase there will be a set of evaluation activities including questionnaires/focus groups/interviews, to determine the effectiveness of using drama and storytelling to engage children with engineering.

1 INTRODUCTION

1.1 Background

Daughters of Invention is a **drama and engineering** project that aims to develop primary school children's understanding of engineering and STEM subjects, raise aspirations and widen their participation in higher education. It also aims to increase engineering students' confidence and skills in outreach and public engagement. The project is delivered by the School of Engineering at the University of Birmingham and The Play House, a theatre in education company with a unique participatory approach to working in schools that uses drama to engage children in a range of subjects and issues.

The project targets girls and children from Black, Asian and Minority Ethnic (BAME) backgrounds in areas of high deprivation in Birmingham. The project consists of a series of four interactive and immersive drama and engineering workshops. It is delivered to 240 children from 8 classes in Year 5 from 4 inner city primary schools. The workshops are led by experienced drama practitioners from The Play House and a team of eight PhD and MEng Biomedical Engineering students from the partnering higher education institution, the University of Birmingham's Mechanical Engineering Department.

Daughters of Invention was originally created through a Royal Academy of Engineering Ingenious award (Ing 718\12\20, 2018) and was delivered to 240 children in four primary schools in Birmingham in 2019. The feedback from the children, teachers and engineers from the first phase was extremely positive and our evaluations demonstrate the project had a significant impact on those involved.

Therefore, a second phase of the project was developed, funded by the the Millennium Point Charitable Trust (STEM Small Grant, 2019) and completed in 2020. This reached a new audience of children and teachers, working with a new cohort of student engineers from Univeristy of Birmingham. We offered 2 student engineers from the 2019 project an opportunity to mentor the new cohort and work with the university to research the impact and potential of the model.

1.2 Literature

The benefits of the use of drama to engage primary school students with science and engineering is widely discussed in the literature. Smith and Herring [1] explains that drama is a powerful tool which enables students to connect learning with content. They

draw from their experience and identify that drama enables students to learn through emersing themselves in the experience and empowering them with new knowledge through actively engaging with the activity. This analogy was identified in our workshops, where students were active participants in the workshops.

Of interest to our study is also Abed's [2] study, which investigated the effect of using drama in science teaching with school children. The focus of their study was on students' understanding of scientific concepts and their attitudes towards learning science. They concluded from their study that there is educational benefit in using drama in teaching science, by again describing drama as a powerful tool with the potential to change the mindset of students who previously in their study viewed the tradtional science class as rigid and boring to a post study view of one that is lively and entertaining through the introduction of drama.

Other examples can be drawn from Najami et al. [3] who concluded from their study that embedding drama into chemistry classes contributes to students' curiosity in studying chemistry and positively impacts their grades. While, Boujaoude et al.'s [4] study focused on the effect of using drama as a method to support science students' learning strategy. When compared with their control group, their results concluded that the students' in the drama group were able to demonstrate more informed views on aspects of science. The outcomes of these studies are consistent with our preliminary observations from the first study.

2 METHODOLOGY

2.1 Primary School student workshop framework

A number of fictional characters interacted with the children and the engineers acted as themselves, to provide a dynamic, problem solving, human story for the children to engage with. The narrative focused on a biomedical emergency, where the children had to design, build and test a medical device for fixing a broken bone. The drama brought to life the real story of Mrs Sarah Guppy, an 18th Century engineer from Birmingham. By contrasting the challenges she faced with the experiences of the current engineers we will demonstrate that engineering is a career open to anyone. Daughters of Invention culminated in a celebration event at the University of Birmingham campus, during British Science Week, for the children to share their engineering creations. The creative and engineering team worked with one class at a time, giving a highly participatory and bespoke experience based on the children's needs.

At the start of the project training was provided for the student engineers on outreach and public engagement to prepare them for the project and signpost them to support available at the University of Birmingham. During rehearsals, engineers learnt storytelling techniques and gained an insight into a different way of communicating

their research and journey's as engineers with the public. At the end of the project, there is an evaluation workshop. The framework of the project was as follows:

Intervention 1 – the children are introduced to a female professional footballer who is due to play in the world cup but has broken her leg. The engineers and the characters in the drama enlist them to design a device to fix the bone. The children meet Sarah Guppy, a real life 18th Century engineer, who explains the challenges faced as a woman, and the children act out scenes from her life.

Intervention 2 – the children design, build and test their devices to fix the broken bone. The engineers and the characters teach the children about forces, teamwork, the engineering design process, prototypes and the importance of learning from your failures and trying again. To help the children understand how engineering benefits society Sarah Guppy gets the children to perform scenes showing the impact their device has on the footballer's life.

Intervention 3 – the engineers ask the children to help them with a presentation at the University next week about their journey as engineers. The engineers use storytelling to tell the children what/who inspired them to be engineers as children and their current research. Sarah and the other characters then help the children to improvise scenes from the engineer's life. The children also produce a poster showing their devices.

Intervention 4 –The children visit the Collaborative Teaching Laboratories at University where they present their devices and perform scenes from the engineer's lives.

2.2 Target groups

The schools targeted in Birmingham (UK) had high numbers of pupils from Black, Asian and Minority Ethnic communities, and will be from socio-economic categories NS-SEC [1]5-8 [5] and have over 50% of their pupils receiving Pupil Premium funding. Teachers value the work from this project as being able to engage with children who have limited English and encourage more complex vocabulary, particularly effective for children who are functionally bilingual. This project introduced the children to engineering concepts and terminology in a supportive environment where they were safe to explore new ideas and make mistakes.

When recruiting the engineering students we identified female engineers and students from BAME backgrounds (our two priorities), to showcase the diversity in engineering and promote the inclusivity agenda. PhD students who took part in phase one shared their experiences and we used the promotional film to inspire potential project candidates. These testimonials delivered a powerful message and resonated with other likeminded students. In addition, personnel from the main project team are from BAME backgrounds and underrepresented groups in engineering, which will strengthen our take home message.

[1] National Statistics Socio-economic Classification

2.3 Workshop Evaluation methodology

The evaluation activities described in this section were approved by the University of Birmingham (UK) Ethics Research Committee.
The evaluation consists of:

1) a pre and post project evaluation questionnaire to be completed by:
- Students from the University of Birmingham
- Children completing the workshops (Under 18 population)

2) Separate focus group sessions post project for each of the following groups:
- Children completing the workshops (Under 18 population)
- Drama practitioners from The Play House

3) Separate individual interviews for:
- Teachers from the primary schools participating in the workshop

3 RESULTS

The analysis of the evaluation data focuses predominantly on the post project feedback, since this is more readily available in the current COVID-19 emergency measures. The following areas can be reported.

3.1 Analysis of evaluation data: Post project evaluation questionnaire (university students)

The 8 university students were asked to reflect on their experience and rate on the following:
- *How would you rate your level of confidence when talking to the general public about your work (from a scale of very confident to not at all confident)*?

8 students responded and the results are shown in Fig.1.

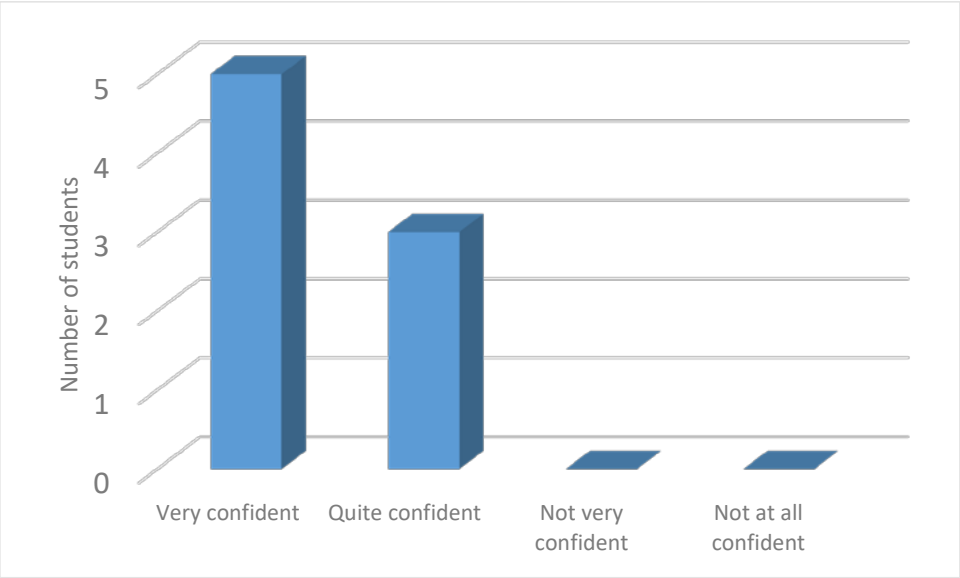

Fig. 1. Confidence level post project

The 8 students were asked to reflect on the following:
- *Which of the following benefits did you gain from this project?*

8 students responded and the results are shown in Fig.2.

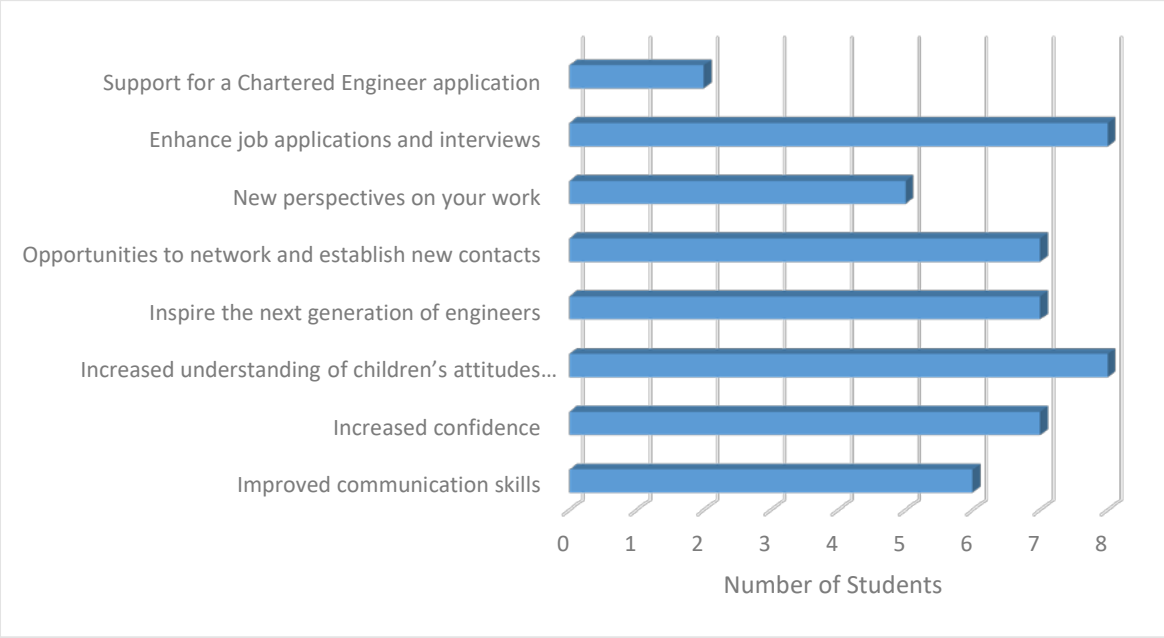

Fig. 2. Benefits of participating in the project

Following these, within the free-text sections students were asked to reflect via a series of questions and a summary of the responses is included below.

- *Was the project enjoyable? Please share why or why not?*
"I really enjoyed it! Never thought of combining engineering and drama together to teach kids about engineering"
"it involved many of the things I like – working with kids, acting, public speaking (and talking about myself). It felt like the kids were really engaged, retained info well and enjoyed."

- *What were the two main learning outcomes for you?*
-Be confident about myself in terms of public speaking
-To improve my communication skills with the children
- To value my own story and be confident in sharing it
- Combination of group activities with theatre is an effective method of outreach
- I should aim for simplicity and study my audience very well
- Being able to demonstrate to school children that Engineering and other STEM subjects are those they can feel empowered to undertake
- great reminder that teachers have questions about other careers too, and it helped me think about how you can educate two different groups of people at the same time
- I learnt how to adapt my speech/presentation skills for different groups and to recognise which things they might and might not engage well with
- How to present engineering ideas in a way children can understand

- *In what ways has being part of the project changed your attitude to public engagement?*
-I would like to continue outreach work when I join the engineering industry, and help students in school or university to explore the industry.
- I got to see it in a new light because I wouldn't immediately think to explain engineering to children in this way – involving figures from the past, mixed with the present day, but it worked really well and I would be a lot more confident to do something like that again.

- *In what way has being part of the project changed your attitude to working with young people?*
-I love inspiring young people and from previous experience, it's amazing what students can achieve with just a little inspiration and push.
- I wouldn't say it's changed my attitude much as it's something I've done one and off for a while, but it did reignite my desire to continue working with children and reminded me why I love it.

For the final two questions, the students were asked to reflect on the two following questions:

- *In what ways has being part of the project developed your skills?*
- *In what ways has being part of the project enhanced your career?*

There was much similarity between the key descriptors reported by the 8 students, as shown in Fig. 3.

Fig. 3. Skills and career descriptors reported

3.2 Analysis of evaluation data: Post project focus group sessions (school children)

The school children were asked to reflect on their experience and asked the following questions.

- *What skills do you think you need to have to be an engineer?* The key words used are summarised in Fig.3.
- *What did you enjoy doing the most as a part of the project?* The key words used are summarised in Fig.4.

Fig. 3. Skills needed to be an engineer

Fig. 4. Enjoyed the most

Following these, the school children were asked to reflect on the project via a series of questions and a summary of the responses is included below.

- *How is problem solving good for doing engineering*? Students identified:
Not all the answers come to you, sometimes you have to dig deeper. It is not just there for you to pick out; to try different ways to get it right; need to figure out how to do it carefully; solve problems quick if you good at it and rapidly help people sometimes things may not go the way you expected and have to pick yourself up again and try again; if you make prototype and afterwards there is something wrong with it, then when you actually do the thing you can figure out what is wrong with it.

- *How is being creative good for doing engineering*? Students explained:
To figure out different ways of doing things to it and add more flare and more things to improve it; It will look very nice and you will have a better design.

- *What did you enjoy the least?* Students identified:
Team work challenges; time restrictions

- *What could have made this project better?* Students identified:
Focus on different subjects and outdoor actitvies and more drama activites

3.3 Analysis of evaluation data: Post project individual interviews (primary schools teachers)

The school teachers were asked to reflect on their experience and asked the following questions. To date one teacher has responded and full responses are quoted below.

- *What impact has this project had on the children in your class?*

"This has a profound impact on the children in both our classes, they have grown in both confidence and understanding of STEM and in particular Bio- Mechanics. During the project some children were interviewed for the UNICEF Rights Respecting Schools Silver Award and spoke at length about the project to the assessors. The assessors said that they had a tone of assurance and knowledge as they explained how they were helping a footballer who had been injured. Most children would not have known anything about bio - mechanics and certainly not the parallels between the mechanics of bridge building and that of current engineering. But now they do and so will their families, so the project has a far reaching impact."

- *Has this project increased the children's experience of STEM?*

"Yes of course. To spend focused time with people who are highly knowledgeable on a STEM project set within a creative frame so that the children can fully access it has given them the chance to have a deeper learning experience. I think that because it was a STEAM as well as STEM project it was most effective. The children responded to the needs of the athlete and loved 'meeting' Sarah Guppy too. This way of working

included a range of different learning styles which meant all children were able to experience STEM in a way that they would remember in the future."

- *How will it support your teaching?*

"It will be something that has shown both teachers children responding to science through a dramatic frame and how that can be effective. The children will take this experience into Year 5 and 6 and further into secondary school. I did a drama session on the project afterwards and the children were able to explain the mechanics, the modern day dilemma and the story of Sarah Guppy."

- *In what ways has this project raised the children's aspirations?*

"Most of our children have had quite a limited experience of things outside their realm so we as a school make it our aim to raise aspirations and give them those additional opportunities which might inspire them to become a scientist or architect or performer. This project has opened their eyes to the learning opportunities for those who are interested in engineering; it will have explained what engineering actually is and it has also shown them that you can be a female engineer. It was a shame they didn't get to the university but they do go in year 5 and 6 and so that understanding that they don't have to go away from home to aspire is also important."

- *Is there anything you would change or do differently?*

"It worked really well as it was. I would, having worked with them between sessions, perhaps set up some kind of recap for either the teachers to do or at the start of the session before you develop the story/ knowledge. I found that some children where a little confused and needed a bit of unpicking before they could fully participate in the drama work (whereas some got it all) - a week can be quite a long time when you are 8 years old, particularly if your first language isn't English and you are taking in many many things during that week.
It wouldn't need to be long (and you may already do it) but a 5 minute recap - including some of the scientific knowledge - would bring everyone on board and ensure anyone who missed a session is clear. I know teachers could do this but if you do it there is a clarity and purpose that is slightly different."

4 SUMMARY AND ACKNOWLEDGMENTS

Both the quantitative and free text responses collected through the evaluation activities demonstrated that the project objectives were met. The children focus group responses demonstrated that they have grasped the engineering pronciples through enagaging with the project. The rest of the project team involved also responded positively and expressed overwhelmingly the benefits and developmental opportunities as a result of their participiption.
The authors would like to acknowledge the funding sources previously identified.

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CHALLENGE BASED LEARNING IN AN APPLIED CELL BIOLOGY COURSE FOR BIOMEDICAL ENGINEERING STUDENTS

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ABSTRACT

Thanks to the technological revolution, university students in the 21st century no longer face the challenge of access to knowledge, but, rather, often lack the opportunity to apply their knowledge to the creation of innovative solutions to real-world problems. To bridge this gap, students need to be encouraged to engage actively in their own learning processes. One method of achieving this in engineering education is challenge-based learning (CBL).

We have introduced CBL into an Applied Cell Biology (ACB) course within the Biomedical Engineering curriculum at Eindhoven University of Technology, along with blended learning and research-based learning as innovative teaching-learning tools to stimulate active learning in students. The aim of the course is to help students respond to educational and professional demands by teaching them how to elevate their factual knowledge to the metacognitive level, thereby finding innovative solutions for real-world scientific problems where fibrosis was introduced as a cellular biomedical challenge. In the course set up, as higher order thinking teaching-learning tools were used, the assignments were also designed according to asses student learning in different aspects where group projects, reports, peer review, peer grading and debating were introduced.

This paper describes the ACB course set up from the perspective of CBL, blended learning and research based learning along with the corresponding assessment plan. In addition, building on the results of the evaluation after the first run of ACB this year, a series of adjustments proposed which will be introduced in next year's course design will also be discussed.

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1 INTRODUCTION

An Applied Cell Biology (ACB) course within a Biomedical Engineering curricula needs to combine teaching and learning methods relevant for both multidisciplinary and interdisciplinary research to solve complex biological problems. As a multidisciplinary and interdisciplinary approach Challenge based learning (CBL) and research based learning (RBL) are used to encourage active learning and stimulation of higher order metacognitive levels as defined in Bloom's taxonomy in ACB course set up. In addition, online educational tools like blended learning and online experimental design tools are implemented along with formative and summative assessments for learning which were able to asses higher order student learning.

1.1 General Course Set Up

The main objective of the ACB course is to learn how to acquire advanced cell biology related knowledge and use it to solve clinical biomedical engineering challenges. For this purpose, in the first three weeks, blended learning and CBL were used. In blended learning, factual knowledge about fibrosis is given by online video lectures along with face to face inspiring lectures and expert lectures. In CBL, students worked in groups of six which are guided by tutors to find innovative cellular experimental designs to overcome fibrosis and they prepared recorded video presentations as an assignment. In the following three weeks, students conducted hands on experiments related to fibrosis in the laboratory, analyzed their data and create laboratory reports as groups. In the final two weeks, students debated on a given fibrosis statement in front of three referees with logical arguments to reflect their learning within the same groups and about the same CBL subject. A final exam composing of multiple choice and open ended questions were conducted to assess their factual knowledge about fibrosis to give individual grades.

1.2 Challenge Based Learning (CBL)

CBL can be defined basically as to find a solution for an unmet need. CBL is an efficient and effective framework for learning while solving real-world 'Challenges' which are provided as 'Big Ideas'. After the definition of a Big Idea, CBL offers a collaborative and hands-on framework consisting of three different concepts termed as Engagement, Investigation and Implementation. In engagement, all participants are asked (students, lecturers, experts…) to identify essential questions to personalize the Big Idea. In investigation, essential questions creates an organized learning experience providing relevant tools to create solutions. In implementation, after the definition of solutions, using the design cycle, learners will prototype, test and refine their solution concepts. Evaluation that provides the effectiveness of the solution is introduced as a final part of implementation [1].
In the ACB course, 'Fibrosis' was introduced as a 'Big Idea', and five different cases of fibrosis were defined along with essential questions to let students engage into the topics. In investigation, students defined different molecular pathways which trigger fibrosis formation and, they selected a target in one of these pathways to solve the fibrosis problem. For implementation, they formulated a research question and designed a cell biological experiment with proper controls. Student used the online experiment design tool Labbuddy to design their fibrosis experiments. Labbuddy has a custom design structure which allows students to select from an assay library and also allows them to add custom assays to their fibrosis experimental design.

1.3 Research Based Learning

Research based learning is an inevitable part of experimental sciences. Research based learning in ACB course compromises both experimental design and hands on practical laboratory work. The high number of students enrolled in engineering programmes makes it difficult to conduct extensive hands-on practical work. However, designing an experimental set up using online virtual laboratories are offering solutions for the high number of students.
In the ACB course set up, we used the online experimental design tool Labbuddy. In Labbuddy, two different experimental set ups were implemented. The first setting was 'in silico experimental design' where students developed a cell biological experiment to solve cellular fibrosis problem. Mainly, there were a range of biological assays where the basics of the assays were explained. Students either chose from these assays or they added custom assays by themselves with relevant controls. The second setting were called 'wet lab experimental design' where the real experiment which they would practice in the laboratory, i.e. the fibroblast to myofibroblast differentiation assay, was implemented. Students were asked to align each experimental step in the correct order to be able to enter the laboratory and do the real experiment.
In ACB, the real laboratory practice were not replaced completely by Labbuddy however the wet lab experimental design is simulated in Labbuddy from the first step to the end. Due to the high number of students they worked in groups in the laboratory. However, Labbuddy enabled them to work individually before entering the laboratory and master each step by themselves.

1.4 Assessment Tools

All the teaching-learning approaches are carefully implemented in the ACB course set up to meet the learning objectives of the course with relevant teaching material, teaching approach and assessment plan. That is why all these components have a unique assignment to ensure to measure student learning in a corresponding cognitive level of learning. And the grades corresponding to all these four assignments weighted meaningfully on the final grade. In ACB, recorded video presentation, experimental report, final exam, peer and tutor review for the CBL sessions and debating grades were given.

2 METHODOLOGY

2.1 CBL as a strategic learning methodology

Learning outcomes of the ACB course were developed regarding to higher order learning skills in Blooms taxonomy. After that, Dale Edgar's 'Cone of Learning Pyramid' considered to select the active enrollment learning activities for students to make them remember the most they learned. At the final step corresponding assessment tools to evaluate the higher order cognitive skills were chosen [2]. Thus, learning outcomes, teaching-learning activities and assessment tools are constructively aligned for the ACB course set up.
Amongst the three most common active teaching-learning methodologies, Design Based Learning (DBL), Problem Based Learning (PBL) and Challenge Based Learning (CBL), CBL was chosen to be implemented in ACB. In CBL, students, tutors and experts have more freedom to find an innovative solution for a societal problem while having more ownership. 96 students were enrolled the course,

students chose their CBL cases by assigning themselves to a specific group. 16 groups of 6 students were assigned to 5 different CBL sub topics (Table 1).

Table 1. Big idea and related sub topics in CBL set up

Big Idea	Fibrosis	Fibrosis	Fibrosis	Fibrosis	Fibrosis
Sub Topics	Extracellular Matrix as a driver of fibrosis	Lung Fibrosis	Kidney Fibrosis	Ocular Fibrosis	Traet of Trigger Fibrosis
Student Enrollment	12 students (2 groups)	24 students (4 groups)	24 students (4 groups)	12 students (2 groups)	24 students (4 groups)

Tutors were recruited as experts from PhD students and Post-Docs working on related fibrosis topics . Each group had bi-weekly meetings with the tutor for the first three weeks. Tutors provided the guidance questions to the students in the first meeting, they gave feedback on the mind map that students prepared about the signaling pathways related to their specific fibrosis cases. Students chose a specific molecule on the pathway to target as a therapeutic strategy and build on their experimental design based on this target. As an assignment they prepared a recorded video presentation to present their innovative experimental design as a solution. Students also gave peer feedback during the CBL sessions which is a part of CBL grading along with tutor grades and lecturer grades.

2.2 The Coherence of the Fibrosis Case Throughout the ACB Course

At weeks 1,2 and 3, students were studied in CBL setting. Students got online learning material about Fibrosis, expert sessions, tutor guided discussions about Fibrosis. As an assignment, they delivered a recorded video presentation as a group. At weeks 4, 5 and 6 students focused on research based learning where they designed the flow chart of fibroblast to myofibroblast transition assay using Labbuddy (online customized experimental design tool) and learned an image analyzing tool then they conducted the experiment hands on in the lab and analyzed their images. At week 7 they debated about fibrosis related statements in the same CBL groups and CBL topics in front of three different referees.
Thus the fibrosis topic which were chosen in CBL setting were used as a topic of different teaching-learning methods throughout the course. This also enabled students to work on the same subject in different aspects and gain higher order meta cognitive skills. In Figure 1, the Applied Cell Biology Teaching-Learning Methods and Assignments in Line with Dale Edgar's Cone of Learning is demonstrated.

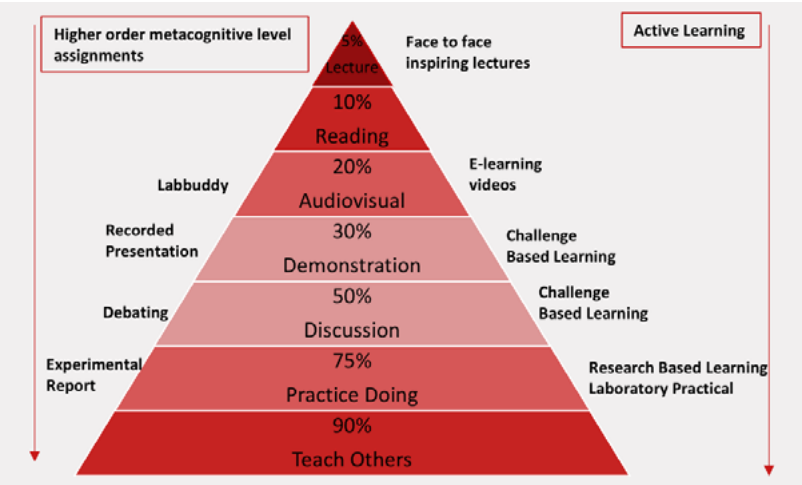

Figure 1. Applied Cell Biology Teaching-Learning Methods and Assignments in Line with Dale Edgar's Cone of Learning

3 RESULTS

3.1 Focus Group Student Meeting

A focus group meeting was organized with five volunteered students to discuss their experience with the first run of ACB course. Students were asked questions about general course set up, course material and administration. The students gave a 6.5 as an average grade for the course but stated that it has a potential to go 8.5.
About general course set up, they mainly like the building blocks of the course, challenge based learning (8), research based learning (8), debating (7.5), online lectures (7.5). Students stated that fibrosis challenge was a good topic to tackle. They appreciate the hands on laboratory work related to fibrosis experiment. They liked using Labbuddy for designing the experiments. They liked debating as a learning tool as they can reflect their ideas more in depth. However, they stated that the debating skills lecture needs to have examples of scientific arguments and scientific debating rather than political.
About course materials, they appreciate the content of e-lectures about fibrosis related topics. However, they stated that Canvas page set up and Labbuddy program set up needs to be communicated in a better way with the students. About course workload, they stated that the workload of this 5 ECTS course felt that higher than other similar courses. However, 5 ECTS corresponds to 140h (28hx5) student workload, and our calculated ACB student workload was 120+/-10 h. For this calculation, each component including face to face lectures, tutor guided meetings, e-lectures, self-study hours (both for the lectures and examinations) were considered.
Due to the first run of the course there were some unforeseen problems to tackle during execuation. However, the course execution and management plan will be implemented to run the course smoothly for next year by using the students' feedback.

4 SUMMARY AND ACKNOWLEDGMENTS

Biomedical engineering is an inherently interdisciplinary field composing of different engineering and biological sciences disciplines. The ACB course designed here fulfilled the gap between factual knowledge to applied knowledge as means of using existing knowledge, acquired data and create solutions within Biomedical Engineering Curricula at TUe which is in line with university's educational vision 2030. Students engaged actively to the CBL topic, gain in-depth subject area knowledge, develop 21st century skills like effectively working in teams, ability to provide meaningful feedback and share their thoughts with society.

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PROFESSIONAL IDENTITY DEVELOPMENT AND CAREER CHOICES IN ENGINEERING EDUCATION: THE ADDED VALUE OF LIFE HISTORY RESEARCH

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ABSTRACT

In the Netherlands, there has been a shortage of qualified technical workforce for many years. This is not only due to the number of students entering engineering degree programmes, but also due to the number of graduates that leave engineering right after their graduation. Around 42% of the engineering graduates does not start working in an engineering job after graduating. Professional identity is a key concept in understanding the study and career choices that students and alumni make.

The project Bridge the Gap is aimed at understanding how professional identity (PI) of engineering students develops over time during and after their studies. Part of this project is a study on PI development from an early age on. In order to understand what experiences in life have shaped their study and career choices, life history interviews were carried out with both alumni that stayed as well as alumni that left engineering after their graduation, 13 in total.

Life history research is a form of narrative research that is about comprehending the complexities in decision making in the daily life of an individual in order to get insight in a collective experience of a group. The nature of the collected data enables us to have a critical look at assumptions about study and career choices of engineering student and alumni, rather than allowing for generalizable conclusions. This paper describes the value of LHR for understanding professional identity development and career choices in engineering education.

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1 INTRODUCTION

In the Netherlands, there has been a shortage of qualified technical workforce for many years. This is not only due to the number of students entering engineering degree programmes, but also due to the number of graduates that leave engineering right after their graduation. Around 42% of the engineering graduates in the Netherland does not start working in an engineering job after graduating [1] and at the same time the number of job openings for technical positions in the Nethderlands has risen from 41.200 at the beginning of 2016 to 71.600 at the end of 2019 [1]. In the search for understanding the large number of engineering graduates that leave engineering, many hypotheses on the motives for staying in or leaving the technical sector have been stated by industry, by universities, by experts on attractiveness of the tech sector for young people and by regional and national administrations. These hypotheses range from the importance of early contact with technology in e.g. toys and games at school or in extracurricular settings, the importance of role models in STEM, especially for girls, the role of parents or study advisors and also the actions that technical companies can take to convince alumni to stay, especially in terms of salary. Based on these hypotheses, many initiatives have been taken to raise interest of young people in STEM, attract more students to engineering degree programmes and increase the number of women in engineering. At the same time, researchers have been trying to understand the study and career choices of those who do or do not choose for an engineering degree programme after their secondary school education, as 42% of students decide – sometimes even before graduating - not to start working in engineering. In order to effectively decrease the shortage of engineers, this phenomenon needs to be understood better. Professional identity has proven to be a key concept for understanding study and career choices [2]. In order to explore the formation of professional identity, life history research can be used to get a more holistics view of the development of professional identity. This article describes the role of life history research in understanding study and career choices of engineering students and professionals through analysis of their professional identity.

2 PROFESSIONAL IDENTITY AND STUDY AND CAREER CHOICES

Professional identity gives an answer to the question “who am I as a professional?”. It describes one´s professional self-concept based on one’s own values and beliefs [3] and it is shaped by the social environment and social situations [4]. It is a concept that plays a key role in understanding study and career choices. Professional identity can be seen as a personal as well as a social construct. When focusing on the personal perspective, professional identity is defined as one’s perception of occupational interests, abilities, goals and values [5], considering as such professional identity as something that is different for every individual. The social perspective on the other hand looks at a group level and describes professional identity as “the degree to which employees identify themselves with the profession that they practice and its typical characteristics” [6]. Previous research shows that

different professional identity profiles of engineering students and professionals are related to their study and career choices: a more prototypical engineer tends to stay in engineering [2]. The profiles also provide insight in the fact that women are more likely to leave the technical sector as they are overrepresented in profiles that have a higher tendency to leave engineering [7].

3 PROFESSIONAL IDENTITY DEVELOPMENT

As professional identity appears to play a key role in study and career decisions of engineering students and professionals, it is important to understand how professional identity is formed. This is studied predominantly in contexts of high school, higher education and early career, assuming that professional identity is shaped during adolenscence and early adulthood. Students do not enter degree programmes as blank slates and begin their education with preconceptions [8]. Professional identity formation of doctors has been extinsevely studied by e.g. Stubbing, Helmich and Cleland [9] through focus groups on experiences and emotions in the process of identity formation during medical school. The trajectory that precedes formal education is acknowledged as relevant, but usually not taken into account systematically. Authors refer to identity development as a continuous process that starts at a young age [10, 11, 12] , but do not take this into account when studying professional identity development. Forsythe [13] simply ignores early stages of identity development when studying professional identity development: “Kegan posits a total of six stages of development (0 –5) of which three are relevant to our discussion of emerging professional identity (stages 2, 3, and 4).” By separating primary and secondary socialisation processes [14], research on professional identity development has a tendency not to take earlier life stages into account, as if the development process of professional identity starts from scratch when entering formal education or just before. The experiences that professionals go through before professional socialisation proceses and the meanings they construct from these processes may however provide useful insights in their study and carerer choices and therefore in the early foundations for professional identity formation. Many experiences that take place before, during and after formal engineering education contribute to the professional socialisation of engineers [15]. As argued by Goodson [16] “… in order to unravel socialisation processes contributing to formation of professional identity, it is necessary to cover the socialisation process during its full span of life and work, as opposed to the training period only.”

4 LIFE HISTORY RESEARCH

When looking for ways to understand the experiences in life of technical alumni, narrative research provides a useful qualitative research framework. Life history research is a specific form of narrative research that is focusing on one’s whole life. Respondents are asked to narrate life episodes of one’s entire life [18]. The specific focus lies on individual stories. According to Cole and Knowles [19] life history research is about: “(…) gaining insights into the broader human condition by coming to know and understand the experiences of other humans. (…) It is about

comprehending the complexities of a person's day-to-day decision making and the ultimate consequences that play out in that life so that insights into the broader, collective experience may be achieved (…) To understand some of the complexities, complications, and confusions within the life of just one member of a community is to gain insights into the collective." The in-depth exploration of these individual stories helps understanding the complexities in the broader context where the respondent is in [19]. It is therefore not only about what is narrated, but also about how the story is narrated. During life history interviews the teller is in charge and tells life experiences without being interrupted or pushed into a certain direction. The role of the interviewer is to ask questions to deepen and further develops the story [18].

5 LIFE HISTORY RESEARCH IN ENGINEERING EDUCATION

In engineering education most research is conducted in a quantitative or mixed-methods manner [20, 21]. Life history interviews have proven to contribute to the research of identity development. To our knowledge, except for the studies of van Hattum-Janssen and Endedijk [22], Tegeler [23] and Paalman [24] within the context of the project Bridge the Gap, no further research has been conducted that explores professional identity based on life history research in engineering education. Within Bridge the Gap, 19 life history interviews have been carried out so far with technical alumni that graduated 1,5 till 4 years before the interview. Both men and women (N = 18) that remained in the technical sector as well as those who left, participated in life history interviews. They were asked to share their life experiences of their early childhood, primary and secondary school, university period and early work life after graduation. The choices they made, what they remember with regard to these choices and how they felt about it were important focus points. Life history interviews have a rather open interview protocol. There is no specific set of information that the researcher is looking for and a structured interview protocol is not appropriate for life history research. An open protocol that allows especially for relation building between the researcher and the respondent and at creating a setting in which the respondent feels at ease to share stories of his life is necessary. In this setting, the respondent will disclose stories of his life of which the researcher and the respondent make meaning. Results of the interviews show that certain patterns for study and career choices made by those who stay and those who leave are, to some extent, already visible before they start their engineering degree programme. Those who stayed in engineering and never really considered leaving engineering show an interest in technical hobbies, tinkering and have engineering related besides school and university. At a young age they already engage in activities that fit well with their future engineering courses,. They hardly ever think about choosing a degree programme outside engineering. The interviewees that are not engaged in engineering related activities have in common that they are characterised by a clear search for cognitive challenge and engineering is a possibility to find this challenge, but it may as well be found elsewhere. As opposed to the first group that will always choose for technical options when study and career choices are to be made, the

second group considers a wide range of options both in and outside the technical field. At secondary school, they tend to choose for a technical profile, because they consider it the most difficult one. During their studies, they go for the most challenging, most demanding specialisations and consider many, sometimes rather divergent options. The life history interviews as carried out with the engineering alumni show an added value of this type of research, but are problematic from time to time, as the individual alumni are often hesitant at the beginning of the interview, have clear hypotheses about why engineers leave engineering and find it hard to imagine what their life story can contribute towards getting more insight, especially coming from a posititvist research paradigm themselves. In general, narrative research can make voices heard that remain otherwise unheard, but, as argued by Brown [25] in his research on narrative research on organisational identity "(…) unlimited plurivocity is, in some respects, admirable, it is also potentially confusing." Plurivocity refers to the potentially limitless number of interpretations of individual narratives.

6 FINAL REMARKS

The life history interviews as carried out within Bridge the Gap seek to enrich the already existing findings of professional identity development in STEM through the inclusion of individual experiences. Rather than presenting conclusions at a general level, life history research helps to understand the individual experiences of professional identity development in STEM. By looking at technical alumni in a different way and taking their life histories into account, the phenomenon of staying or leaving in the technical sector is not reduced to the acceptance or rejection of a specific hypothesis on one or more aspects that may be relevant for study and career choices. It enables us to look at the possible patterns that are coherent with their entire life history and may help us to learn more about how future choices will be made by these alumni. From the interviews in this study, we learnt that the alumni that stayed in engineering and have never considered other options, relate similar life experiences and choice processes. Their study and career choices do not seem to be strongly influenced by external factors like parents, teachers, study advisors or specific programmes to gain their interest for engineering. From an early age, sometimes as early as primary school, these alumni show an interest in the technical field. This interest is not clearly visible in the group of alumni that have considered both staying in the technical sector as well as leaving. Their interest is not in things like tinkering and soldering.They make study and career choices based on their search for cognitive challenges and/or diversity in their work context and professional activities. For them, the technical field is one of the possible options to fulfil their ambitions. The visibility of these different patterns before the period that is usually included in research on professional identity formation makes a case for the inclusion of earlier stages of socialisation into the period of analysis.

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INFLUENCE OF PROJECT-BASED LEARNING ON MOTIVATION OF FIRST-YEAR STUDENTS IN ENERGY ENGINEERING

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ABSTRACT

The way energy is generated and provided is changing rapidly. Many engineers are required to overcome these new challenges. High drop-out rates, especially in engineering study courses, are therefore a serious problem. Hence, new concepts are needed to reduce them.
Factors like study motivation and interest in subjects have a proven high influence on the drop-out rates [1]. Additionally a high degree of identification with the subject and a good professional perspective support the probability of graduation [1], while the method of project-based learning has shown positive effects on the motivation to study [2].
In this study, it will be investigated how project-based learning affects the motivation to study and the identification with the subject of energy engineering students in their first and successive semesters. In an experimental control group design, a new concept will be developed, which shall not only increase motivation but act as a connecting link of the study course by giving an overview of the interrelationships between the

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subjects and accompanying the students as a guiding thread for their studies. While the experimental group will attend a new practical concept with project-based tasks, the control group will deal with topics similar to those of the experimental group, but in a more theoretical context. The motivation and the identification with the subject will be measured in a pre-post-design by questionnaires. A follow-up at the end of the second semester will investigate the medium-term development of the examined variables.

1 INTRODUCTION

The energy demand of mankind is enormous. Many innovative concepts and developments are needed to ensure a reliable energy supply, especially in times of dwindling fossil fuel reserves. To master these challenges, a large number of well-trained engineers is necessary.

However, particularly in the engineering sector, high drop-out rates have been recorded in Germany in the recent years [1]. For the German graduating cohort of 2012, the drop-out rate in engineering at universities of applied sciences was 31 %, which is well above the overall average of 23 % [1]. In accordance with [3], the drop-out rate for engineering students even shows a further increase in the following years.

Dropout can be understood as a process that is driven by different internal and external factors and conditions. One of the main reasons for dropping out is a lack of study motivation. Students no longer identify closely with their chosen subject or career prospects. [1]

According to [3], for 64 % of dropped out engineering students at German universities of applied sciences, study motivation plays a significant or major role in their drop-out process. Furthermore, the dropout due to lack of study motivation can be observed as one of the earliest. 53 % of students, who stated the missing study motivation as a main reason for dropping out, left the higher education institution in the first two semesters. [3]

A method that has proven to show positive effects on students' motivation for their studies is project-based learning [2]. It is based on authentic problems, supported by a driving question [4], which should place the students in realistic and contextualized problem-solving environments [5]. Students can work moreover quite autonomously [4], which gives them room for developing own approaches and choices and engages them in investigation [5]. Furthermore, solving authentic problems increases their interest in the subject [5]. Project-based learning also links among subject matter disciplines and gives therefore a wider view of subject matter [5].

2 AIM OF THE STUDY AND RESEARCH QUESTION

One approach to reduce drop-out rates in the engineering sector can thus be to increase the students' motivation to study. It becomes equally clear that this should happen as early as possible. This study will investigate, how project-based learning tasks affect the motivation to study and the identification with the subject of energy engineering students in their first and successive semesters. It is carried out at a German university of applied sciences.

3 METHODOLOGY AND DESIGN

To promote the students' motivation to study, a new first semester module is designed. It consists of two components, a lecture with integrated exercise and a workshop (Fig. 1). Each component pursues different aims. The lecture gives an overview of the field and creates context in relation to historical developments and future challenges. This conveys in particular the relevance of the topic and creates a subject-specific orientation in the study course. In the workshop, the students investigate technical and scientific interrelationships. This also includes the development of competencies. By gaining the opportunity to get to know the various facilities at the university and the research areas of their faculty, students will feel integrated into academic life at the university from the very beginning. The interaction of both components then promotes the two main objectives of the module concept, increasing the students' motivation to study as well as their identification with the subject and the university.

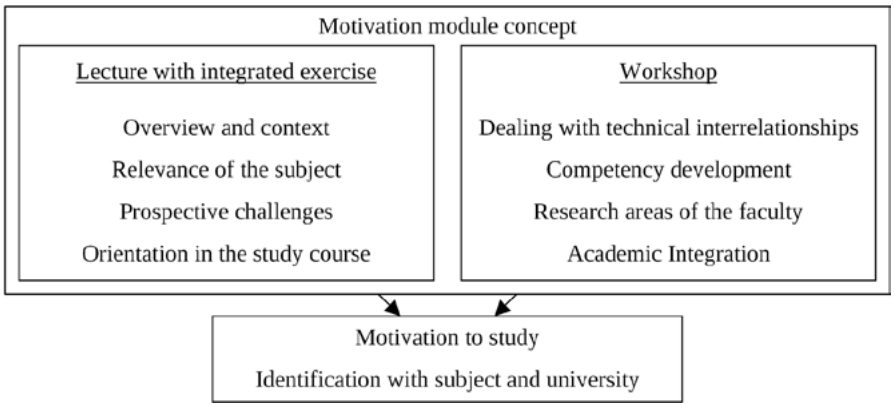

Fig. 1. Structural design of the new module with specification of component objectives

The project-based learning is integrated into the workshop as the independent variable. Its effects are measured in a pre-post-design (Fig. 2). Therefore, a set of dependent variables is defined (Fig. 2). The dependent variables will be measured by questionnaires. With a follow-up at the end of the second semester, the medium-term development of the effects will be investigated.

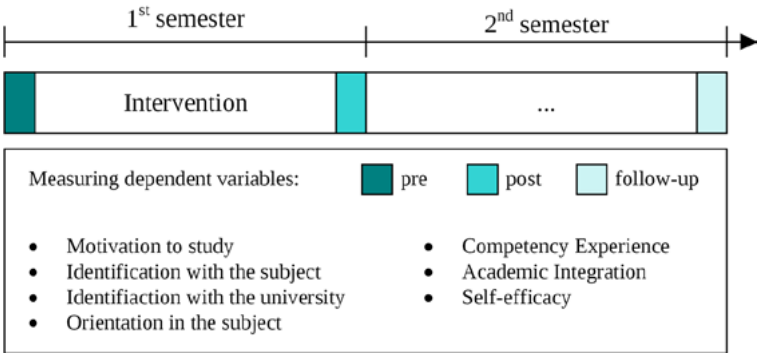

Fig. 2. Design of the measurement

To ensure that the measured effects are due to the independent variable, an experimental control group design is chosen for the intervention (Fig. 3).

All students participate in the lecture with integrated exercise. In the Workshop, the experimental group as well as the control group investigate concepts of modern and renewable energy systems. Both groups will deal with the same topics over the same time in order to be equally prepared for the exam at the end of the semester.
The difference will be that the experimental group works mainly practical in project-based tasks and will be accompanied throughout the semester by a driving question that links the topics to be worked on with an authentic problem. Here, the students will develop a concept for the integration of renewable energy systems in a residential building that is to be renovated. The participants of the control group will work more theoretically by only studying literature about energy systems, but without the connecting element of the driving question and other typical project-based learning elements.

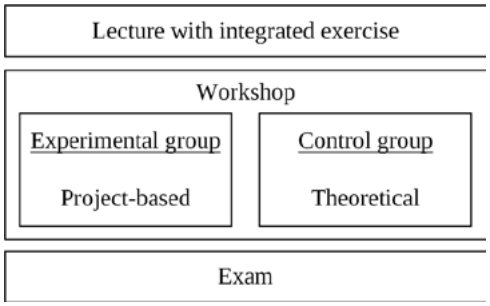

Fig. 3. Structure of the experimental control group design

4 PERSPECTIVE

Due to an expected limited number of participants in winter semester 2020/2021, the planned pilot study will be postponed to winter semester 2021/2022. The pilot study will evaluate the design and the test instruments, that will be selected in a next step.

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A MODULAR, SCALABLE OPEN-HARDWARE PLATFORM FOR PROJECT-BASED LABORATORY COURSES IN ELECTRICAL ENGINEERING STUDIES

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ABSTRACT

Electrical engineering, as well as other technical and scientific study programs, typically include laboratory courses in which students work on practical exercises with electronic circuits. Usually, self-contained hardware for each topic being covered is applied. These pre-build electronic circuits are often complex and not easily understandable at a glance. This hinders in-depth understanding of the topics in the limited amount of course time. Moreover, each time the students are confronted with new hardware, a familiarisation process is necessary before they can start the actual experiments. Typically, each topic is dealt with on a single appointment, thus for the students there is no possibility to experiment, develop routines or to correct misconceptions. To overcome these issues, a modular, scalable open-hardware platform, comprised of small, easily combinable modules, is presented. In the design of a laboratory course for a specific topic, the required experimental setup can be assembled from these modules. Further, the platform allows for a realisation in individual steps, thus encouraging experimentation and enabling the students to gain understanding of each component, e.g. by system identification approaches.

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1 MOTIVATION

Laboratory courses are typically found in bachelor's study programs and mark the first step towards practical work in electrical engineering studies. The students are tasked to apply theoretical knowledge gained in lectures on practical examples. This implies that the course itself is intended to deepen the understanding of newly learned concepts and to learn the correct operation of measurement equipment and methods. In many of these courses, self-contained hardware dedicated to the respective topic is applied. Students are confronted with often complex, monolithic electrical circuits, preventing an in-depth understanding of the components and their functionality. As new hardware is used for every exercise, an anew and often lengthy familiarisation period is required preceding the practical work.

2 METHODOLOGY

2.1 Goals

To overcome the drawbacks of monolithic, single-topic hardware, a new, modular hardware platform is designed. Compared to commercially available electronic modules and kits, which typically either focus on secondary school teaching or digital microcontrollers (e.g. *PHYWE* experimental kits and *Arduino* shields), the platform allows for rather complex, multi-stage analog circuits to be build.

There are different models to describe experiential learning, but they all regard experiential learning as an iterative process, which generates and updates concepts from experience [1]. To foster this process, students should be allowed to develop their own approaches without following recipe-like instructions. Thus, the hardware platform is designed with project-based courses in mind. Moreover, a project-based approach can increase the motivation of the students, as the focus is shifted from merely finishing the course to the development of individual solution strategies [2]. The main characteristic of project-based learning is that there is a goal, which is specified beforehand [3]. This specifically fits laboratory courses as many tasks can be formulated in a similar way. The advantages of using project-based learning [2, 3] match the skills a laboratory course should convey, as described by the following goals:

a. Promote engagement of the students: Students know methods from lectures, but have only limited experience in the application of these methods. A modular design allows for an individual realisation of the experimental setup, which encourages the students to try out various approaches.
b. Promote analysis and synthesis: Students learn to connect theory and practical realisation, e.g. by designing a block diagram and synthesising electrical circuits from it.
c. Build and use correct terminology: Using correct terminology is essential for a laboratory course as it forms the basis for well-founded discussions and the written reports.
d. Further collaboration: This aspect is two-fold, as collaboration takes place inside participating groups themselves, but also between the different groups.

The following section describes how these goals can be achieved by using a modular hardware platform.

2.2 Modular, scalable hardware platform

The fundamental element of the platform are small, generic modules representing elementary functions. This reduces complexity to blocks typically present in electrical systems, such as voltage supplies, bridge circuits, filters and operational amplifier circuits.

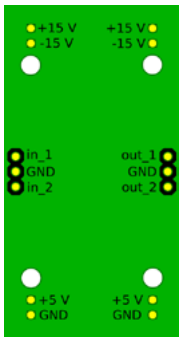

Fig. 1. Module template.

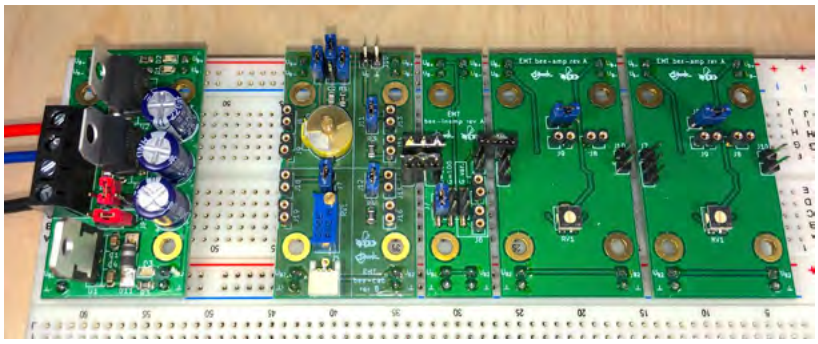

Fig. 2. Exemplary setup with several modules mounted on a breadboard.

The template of a module is depicted in fig. 1. The lower surface of each module has pin headers to connect to the power supply. On the top surface, different pin headers for inputs, outputs and ground can be realised. The basis of the platform is a standard breadboard, as illustrated in fig. 2. This simplifies voltage distribution and allows for additional electrical components to be placed. Besides the electrical connections, the breadboard also provides mechanical stability. Compared to pre-built hardware, this provides flexibility and scalability, as arbitrary combinations of modules can be used. Moreover, new functions can easily be integrated by designing a single, new module. Due to the segmentation of elementary functions, each module can easily be analysed on its own, e.g. via system identification methods, to further in-depth understanding. An experimental setup can be realised individually by the students, which is essential for project-based learning. The existing module designs and templates are published as open hardware [4]. Course instructors are encouraged to apply and extend the available modules in the design of their own laboratory courses.

2.3 Example of usage in a laboratory course

In the course taught by the Measurement Engineering Group at Paderborn University, a gravimetric measurement is to be realised using a capacitive force sensor. The project goal is to determine the mass of an arbitrary object. Groups of three students are provided with the documentation of the available hardware modules and are tasked to develop a suitable block diagram (goals a, b). These diagrams are presented and discussed on the first appointment, which enables the groups to compare and evaluate their solutions on their own (goals a, d). The teacher moderates the event and gives remarks if needed. Thereafter, the experimental measurement setup is realised individually by each group (goal a). At specific points (matching the student's progress and reacting to problems) the teacher interrupts the group work to begin a discussion, in which the students try to solve problems (goals a, c, d). At the end of

each meeting, a conclusion is drawn in plenum and a working plan for the next appointment is set up to synchronise the findings of the groups. After finishing the project, the students write a report, which is especially reviewed with regards to correct terminology (goal c).

3 RESULTS

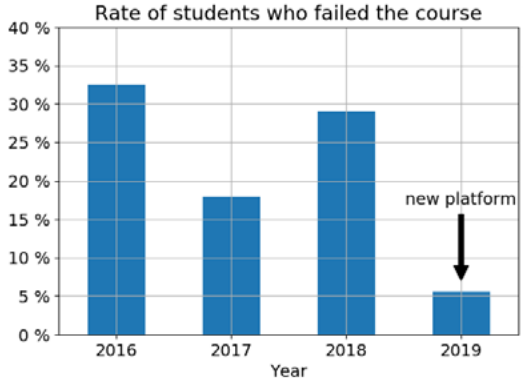

Fig. 3. Comparison of dropout rates over previous years

Tab. 1. Average grade in previous years. Note that grading was introduced in 2017.

Year	Average grade
2016	n/a
2017	2,40
2018	2,76
2019	2,54

Fig. 3 depicts the percentage of students who failed the course in previous years. First of all, the new platform introduced in 2019 led to a significant drop in the dropout rate to 5.6 %, compared to from 18.0 % to 32.5 % in the preceding years. A comparison with the average grades for the respective years (tab. 1, grades range from 1.0 (best) to 4.0 (worst) with 5.0 denoting a fail) shows no significant decrease. This suggests that the decrease in the dropout rate is not achieved by a reduced difficulty of the course. In personal conversations with the students, they emphasised that they liked the possibility to experiment freely. Furthermore, they stressed that they prefer the project-based approach in comparison to the typical structure of working on a single topic per appointment.

4 SUMMARY AND OUTLOOK

A new hardware platform for project-based laboratory courses is presented. It is shown that the application of the new platform led to a lower dropout rate. The platform idea can easily be picked up by other groups, which is currently in progress at Paderborn University.

As the modules are generic, they can also be used for other purposes, e.g. for quick circuit setups in daily laboratory work. Due to the modular nature of the setup, tasks can be scaled to the abilities of the participants. The hardware platform can also be used in secondary schools for small experiments to raise interest in engineering studies or in laboratory courses of other fields, e.g. when a sensor interface is needed.

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KEY SKILLS DEVELOPMENT IN INDUSTRIAL ENGINEERING EDUCATION

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Conference Key Areas: Interdisciplinary engineering education; Future engineering skills and talent management.
Keywords: *"Key Skills Development", "Industrial Engineering & Management"*

ABSTRACT

In order to successfully shape a disruptive, volatile and digitized world, industrial engineers need (beyond their professional skills) methodological and social competencies more than ever. Scope of the research was to find out which competences, personality traits or value settings are essential for a successful career as Industrial Engineer (I.E.) particularly in a cross-functional working environment. Hence, engineering education has to find ways on how these competences can be developed during the BA/MA study programs?
A qualitative research design was deliberately chosen. In total 50 I.E. experts from various backgrounds were interviewed in order to increase the understanding of the skills and competences required in a typical I.E. working environment.
The results clearly highlight the importance of key competences for a successful professional as well as for a leadership career.

1 INTRODUCTION

1.1 Industial Engineering Education

Industrial Engineering education traces back to the late 19th century when selected American universities highlighted the need to bridge the gap between technical expert knowledge and economical expertise. Also in industry, professionals very often work in their field of specialisation without having a holistic overview of the whole "system".
In Germany the first Industrial Engineering academic program started in 1927 at the Technischen Hochschule Berlin-Charlottenburg. Since than I.E. Education quickly evolved into a very relevant study program with more than 100 universities/ higher

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education institutions (Germany/ Austria/ Switzerland) offering IE study programs starting from Bachelor to PhD level.

1.2 Requirements for Industrial Engineering Education

Industrial Engineers are engineers with a solid foundation in economics as well as in social science. In their professional work they combine technical, social and economical aspects in a holistic way [1]. According to the national framework of the German Industrial Enginneering Education association (VWI) the curricula should include more than 50% technical modules, at least 20% modules related to ecomomics and business administration as well as minimum 10% integrative skills [2]. The professional working field of industrial engineers is very often in cross-functional settings. Statistics clearyly indicate that approx. 75% of I.E. graduates pursue a management or leadership career.

1.3 Overcoming the skills mismatch

The higher education system is very much based on conveying expert knowledge in various fields. Undoubtedly this is a major prerequisite for success in the working environment. However, many investigations clearly indicate a mismatch between knowledge taught in tertiary education and industry requirements as shown in this figure:

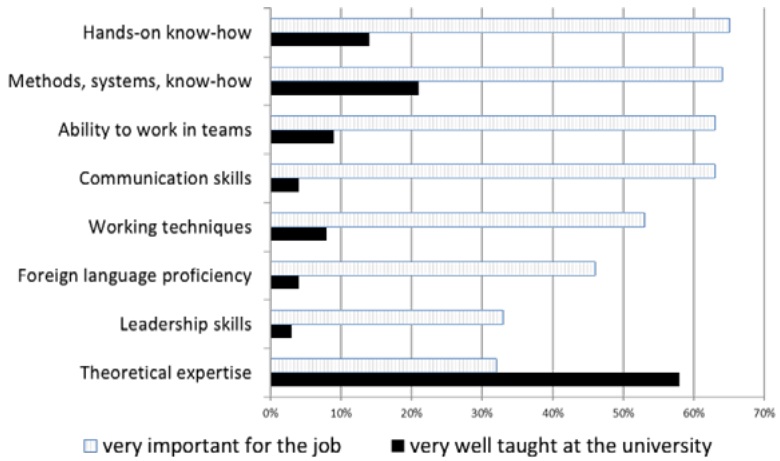

Fig. 1. disparity between knowledge taught at universities and know-how required at workplace [2]

1.4 Scope & reseach questions

The scope of this investigation was guided by the following two research questions:

- Which competences, personality traits or value settings are essential for a successful career as an industrial engineer especially in a cross-functional working environment?
- How can these competences be fostered during a BA/MA I.E. study program?

2 METHODOLOGY

2.1 Research Approach

The research is based on a literature review. Relevant publications especially from the Industrial Engineering Associations were investigated. Very often these investigations are based on qustionnaires/ quantitative research.
However, for this study a qualitative research design was deliberately chosen. About fifty 1:1 interviews were conducted. From a methodical point of view, these were semi-structured, narrative interviews with the goal to better understand the perception of the experts. Average duration of each interview was about 50 minutes. A written consent form had to be signed by each partner. In addition an information sheet was given to each interview partner with a thorough description on how the material will be processed. Full anonymity was also assured. Each interview was recorded and fully transcribed.

2.2 Expert Selection/ Interview Partners

In total, fifty I.E. experts from various backgrounds were interviewed:

- Industrial engineers in top positions
- Industrial engineering senior lecturers
- Industrial engineering graduates

2.3 Data Processing & Evaluation using GABEK

GABEK ® [3] (Holistic Processing of Complexity) is a PC-supported method of qualitative research and text analysis (QDA). Based on open interviews or other verbal experiences, the knowledge and attitudes of many people are networked in order to acquire a well-founded overview. GABEK ® translates opinions of interview partners into termed knowledge systems. These systems provide a meaningful orientation for understanding the whole landscape of opinions. Every step of analysis can be interactively reconstructed and the results can be checked. For further information please see www.gabek.com.

3 RESULTS

3.1 Perception of experts

- The interviews clearly confirm that Industrial Engineers mainly work in cross functional settings
- Beyond the professional hard skills there is a clear challenge to interact with others in order to solve complex problems in an ever faster environment

- According to the interviewed experts the working environment can be described with the VUCA acronym [4]: volatile, uncertain, complex, ambiguous
- There is a need to build up intra-personal ("know yourself") and inter-personal competences (ability to interact with others in multi-national/multi-functional settings)
- For a successful career a very strong attitude to perform seems to be essential
- Moreover situation-appropriate communication, problem-solving capabilities, willingness for lifelong-learning, network ability, ongoing reflective self-management, risk assessments and network-oriented thinking in addition to professional competences are essential success factors

3.2 Impact on Industrial Engineering Bachelor & Master Program

Based on research findings incl.literature [5] the current curriculum is under adaption. In general more problem & project based learning was included. Real life / business case studies are introduced. Further changes that are still under development were:

- Introduction of a lecture in systems engineering including also the usage of systemic question techniques
- Training the use of small group moderation, peer feedback, collegial advice for real life challenges
- Development of a presention seminar including trainers with an actor`s background
- Introduction of business simulation games including Change-Management to experience team/group dynamics
- Development of monthy open lectures with industry experts from various field in a "Fire side chat setting".
- Broadening the holistic view of students by including aspects related to the six PRiME principles (Principles of Responsible Management Education) including the 17 SDGs (Sustainable Development Goals)
- Fostering the international perspective by offering a semester abroad & short term study tours
- Offering badges from university career center (beyond the traditional curriculum)
- Development of a mentoring system (graduates-students)

The underlying educational philosophy is based on a quote of former Management Expert Prof. Henry Mintzberg: Learning occurs where concept meets experience through reflection [6].

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DEVELOPMENT OF CRITICAL AND CREATIVE THINKING IN STEM EDUCATION

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Keywords: *STEM education, misconceptions, critical thinking, video analysis, FCI*

ABSTRACT

Critical thinking has been integrated into STEM (Science, Technology, Engineering and Mathematics) curricula in many countries. This paper attempts to clarify the relationship with scientific literacy and conceptions and to discuss a framework for promoting students' critical thinking in teaching and learning physics.
An interactive approach of teaching physics forces students to work and think independently and enhance their active learning. Moreover, watching the real videos and doing video analysis of motions with the help of the program Tracker (video-analysis and simulations (VAS) method of solving problem tasks) helps them to see the discrepancies between their preconceptions, misconceptions and scientific concepts.
Using a standardized FCI (Force Concept Inventory) pre and post-tests we analyzed the teaching and learning processes during last three years. VAS method helps us to eliminate some student's misconceptions and enhanced students' conception connected with STEM education.

1 INTRODUCTION

The focus on processes of critical and creative thinking is required for next problem-solving, project-solving, decision-making and scientific research. The creative use and transfer of these thinking abilities in which students are expected to become more aware of their own thinking processes and better informed about the thinking strategies of others.
As Paul Hewitt claimed, "Science is a way of thinking as well as body of knowledge" [1]. Other authors declare that science requires the use of elementary clarification abilities to identify or formulate a question:

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- Basic support capabilities and elementary and advanced clarification abilities in order to search and select information in credible sources.
- The ability to design experiments and also the use of strategy and tactics abilities when presenting a report.

Therefore, it seems that critical thinking has an important role in science learning and consequently, in physics learning [2].
Critical Thinking is a major development goal of the science education industry. Projects/Tasks/Studies that require prediction, analysis, synthesizing, evaluation and reasoning, etc. [3] are all areas where critical thinking skills are a necessity [4, 5].
This is why we have turned our research attention to critical and conceptual thinking. Because, it's absolutely critical for us to further study problems in Newtonian mechanics.

2 METHODOLOGY

Students at the University of Žilina, Faculty of Electrical Engineeing and Information Technology (FEIT) attended compulsory Computational Physics exercises and lectures that were optional. The subject named 'Introduction to Physics' consists of 2 - 1 - 0 (lectures - exercises - labs) lessons per week. One lesson lasts 50 minutes. The term consists of 13 weeks.
We used Force Concept Inventory (FCI) test [6] to verify prior students' knowledge of Physics (Kinematics and Dynamics). It contained 30 qualitative multiple choice tasks that focused on conceptual understanding of Newtonian mechanics. FCI was given to students to find out prior knowledge level of physics at the beginning of the academic year. The pre-test was carried out at the beginning of the term during the first week and it was attended by 129, 122, 199 students (students participated in both pre and post-tests) in the academic years 2017/2018, 2018/2019 and 2019/2020, rrspectively. Post-test was carried out at the end of term after finishing the course 'Introduction to Physics'.
During lectures the VAS method of problem tasks was used, at the beginning of lecture problem tasks were critically discussed by students in small groups, then students have presented their views, they watched the real videos later on and finally, lecturer used video analysis of motions with the help of the program Tracker for the explanation of the natural laws in Newtonian mechanics.

3 RESULTS AND DISCUSSION

As we can see in Fig. 1, results in Pre-test are comparable. We can declare, that there is no statisticaly significant difference between the mean (M) at the beginning of term (we used F-Test: Two Sample for Variances and t-Test: Two Sample Assuming Unequal Variances: 17/18: N = 129; M = *31.19*; SD = 14.32; 18/19: N = 122; M = *33.97*; SD = 14.63; 19/20: N = 199; M = *32.93*; SD = 14.41). The same situation is also in Post-test: there is no statisticaly significant difference between the mean at the end of term (we used F-Test: Two Sample for Variances and t-Test: Two Sample Assuming Unequal Variances: 17/18: M = *39.10*; SD = 16.20; 18/19: M = *41.31*; SD = 16.50; 19/20: M = *39.40*; SD = 16.54). But in the same academic year, there is statistically

significant difference between the mean of pre and post-test FCI score (we used t-Test: Paired Two Sample for Means, p < 1E-14 (a.y.19/20)).

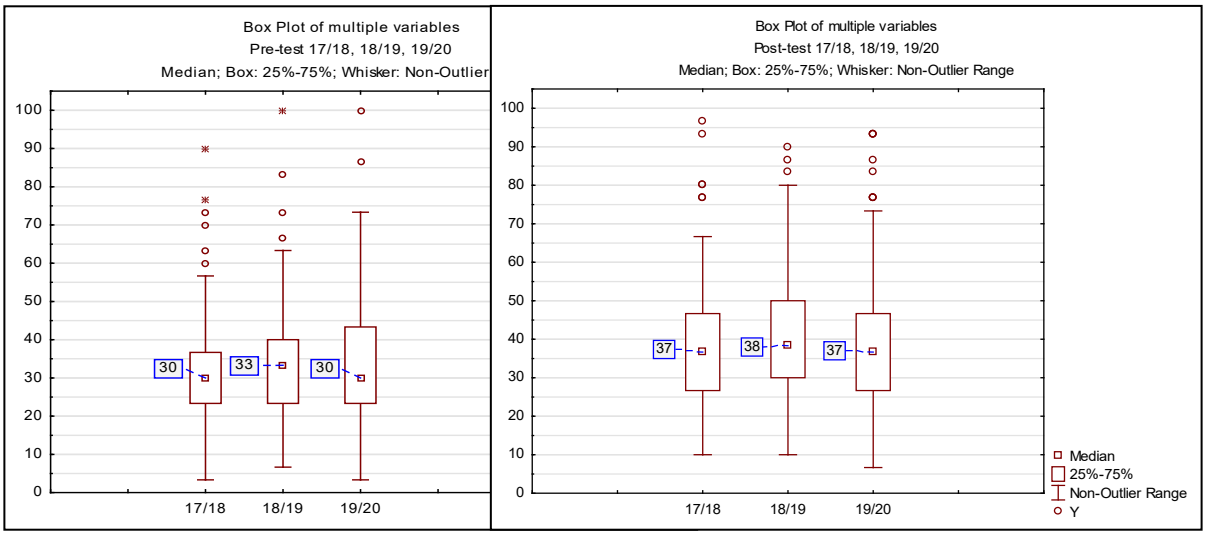

Fig. 1. Box Plots of Pre and Post-test FCI results in individual academic years – 17/18, 18/19, 19/20.

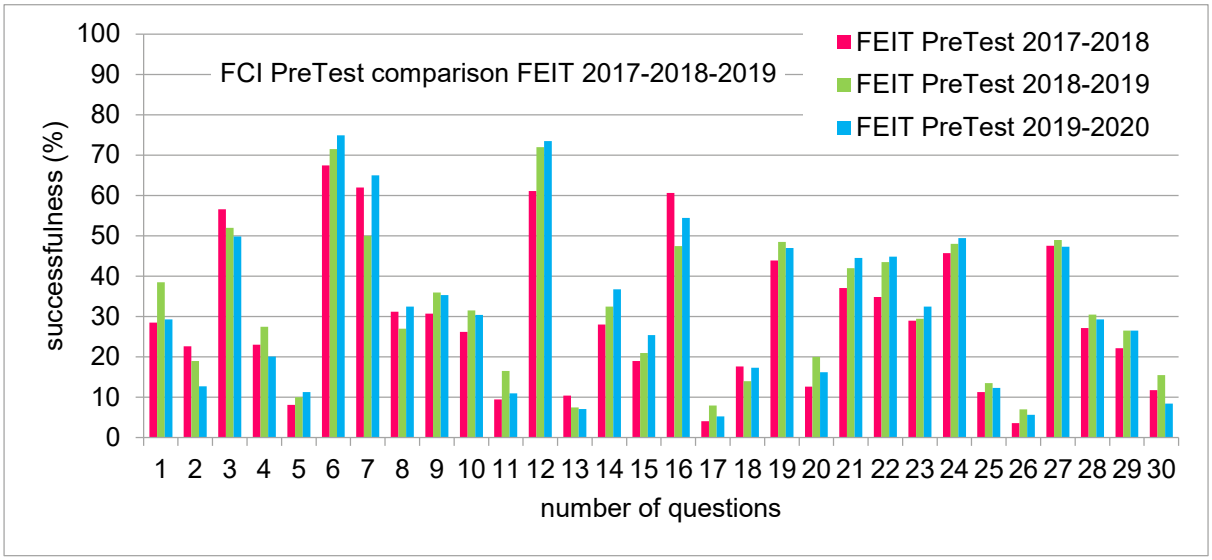

Fig. 2. Analysis of individual questions of FCI Pre-test results in individual academic years – 2017/18, 2018/19, 2019/20.

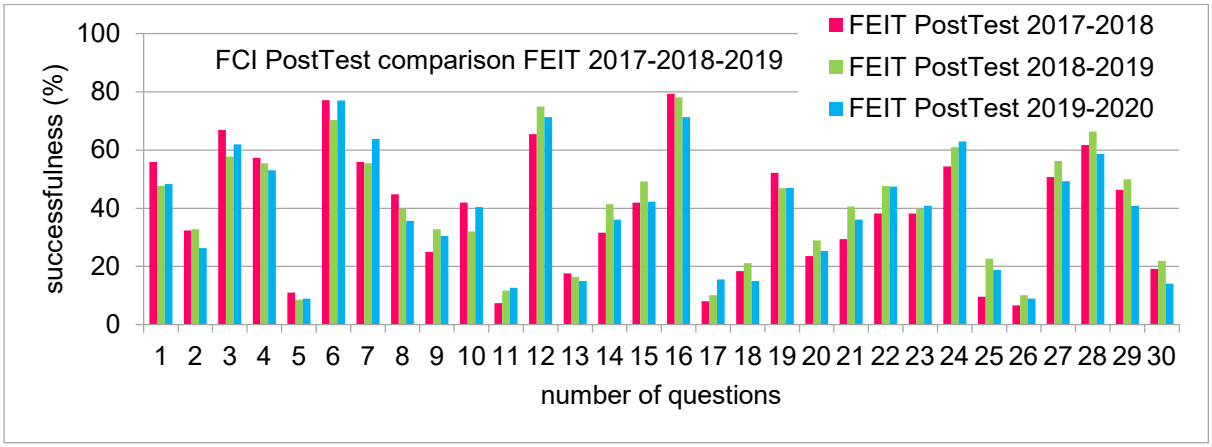

Fig. 3. Analysis of individual questions of FCI Post-test results in individual academic years – 2017/18, 2018/19, 2019/20.

Detailed analysis of individual questions helped us find some misconceptions, e.g.: *"greater mass implies greater force" (*questions: Q4, Q15, Q16, Q28*)* and *"most active agent produces the greatest force" (*questions: Q15, Q16, Q28*)* (Tab. 1). For explanation of the Newton's Third Law: Action/Reaction Pairs we used video of head-on collide of a truck with a small compact car.

Table 1. Analysis of particular questions in individual academic years

		The biggest of incorrect answers [%]			Correct answer [%]		
	Ac.year	2017/18	2018/19	2019/20	2017/18	2018/19	2019/20
Q4	Pre-test	72	69	76	23	28	20
	Post-test	41	40	44	57	56	53
Q15	Pre-test	58	58	55	19	21	26
	Post-test	49	41	43	42	49	42
Q16	Pre-test	24	32	30	61	48	55
	Post-test	15	12	18	71	78	71
Q28	Pre-test	49	46	46	27	31	30
	Post-test	26	21	32	62	66	59

To calculate the normalized average gain *g* we used Hake formula [7], where the difference between the total percentage of students in the Post-Test and the Pre-Test was divided by the difference between 100% and the percentage of students in the Pre-test:

$$g = \frac{Post_test - Pre_test\ [\%]}{100 - Pre_test\ [\%]} \tag{1}$$

The gain $0.3 < g < 0.7$ means teaching was effective (Tab. 2).

Table 2. Analysis of the normalized average gain *g* in individual academic years

	Academic year		
	2017/18	2018/19	2019/20
Q4	0.45	0.38	0.41
Q15	0.28	0.36	0.22
Q16	0.48	0.58	0.37
Q28	0.48	0.51	0.41

4 SUMMARY AND ACKNOWLEDGMENTS

Our research has pointed to the fact that the students entering to university have difficulties with conceptions of Newtonian mechanics. Deep analysis of some answers in Pre and Post FCI tests shows us that there are differences in knowledge of students at the end of term connected with using VAS method.

Future deeper analysis can help us to find and eliminate the misconceptions of the students and also to improve teaching methods and students' level of knowledge in the introductory courses of general Physics, mainly in the field of Mechanics. It can be useful for building of critical thinking of students in their future study of STEM.

ACKNOWLEDGMENTS

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ALICE AND EVE: A CELEBRATION OF WOMEN IN COMPUTER SCIENCE

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Keywords: *Diversity, Innovation, Role Models, Self-Efficacy*

ABSTRACT
In most Western countries, women account for no more than 20% of the total population of computer science students. This is regrettably low, for it is frequently underscored that diversity is important for the development of creative solutions. Undergirding this imbalance is that, historically, computer science is mostly being remembered as a male endeavour even though women have contributed substantially to its emergence. In response, the *Alice and Eve*-event wishes to celebrate women in computer science. By exposing the female achievements across computer science history, aspirant female students are provided with the role models they need to confidently pursue a similar computer science path.

In order to support this rationale, the event consisted of an *exhibition* and a *symposium*. In the exhibition, attendees are made familiar with both female pioneers and with contemporary, yet leading scientists within the field. The symposium allows the

attendees to interact directly with their female role models, seeing technically interesting topics being discussed. Notably, the event aimed at celebrating female achievements with pride, rather than discussing them within the shadow of their male counterparts.

In retrospect, the event has been met with critical acclaim. More specifically, attendees have praised the elucidation of female trailblazers. In light of this appraisal, the organization wishes to expand both its content and its audience. Moreover, it is believed that the Alice and Eve-event could serve as an example toward other engineering fields that are experiencing a similar gender imbalance.

1. INTRODUCTION

In most Western countries, the proportion of female students enrolled in computer science courses accounts for approximately 20% of the total population of computer science students. This number is regrettable low as it is frequently underscored that diversity is one of the main ingredients in the development of creative solutions. Notably, renowned computer scientist William A. Wulf expressed his belief that "[engineering] is a profoundly creative profession", buffeted and bounded by 'life experiences' [1, p. 8]. If women are not involved in this process, society is denying itself the grand benefit of their talents in addressing the world's most pressing challenges. As such, Wulf appears to be a spiritual heir to the late philosopher John S. Mill, who already proclaimed two centuries ago that "the existing social relations between the two sexes [...] is wrong in itself, but now one of the chief hindrances to human improvement" [2, p. 1]. As it appears, his proclamation remains painfully relevant for today's digital world.

Fortunately, efforts have been made to counter this imbalance. Among these efforts is *Alice and Eve*, an academic event that wishes to celebrate women in computer science. Its underlying rationale is simple yet solid: by making women familiar with the female achievements across computer science history - up until the here and now - they will find it easier to imagine themselves enlist to a similar computer science path. The purpose of this paper is to demonstrate how the event has intended to make this reasoning come into fruition.

2. METHODOLOGY: SEEING IS BELIEVING

Indeed, as mentioned, the goal of Alice and Eve has been to expose how the field of computer science has been lifted to its current height equally by female contributions. Today, far too few people are aware of this. Upon mentioning computer science, that is, the first names to come to mind are Alan Turing, Edsger Dijkstra, Steve Jobs and Bill Gates. Perhaps, then, it should be of no surprise that it is primarily male students that engage with the subject. Role theory tells us that "people don't attempt to achieve something unless they believe it can be done" [3, Section 3]. Seeing is believing, it seems. Yet, if the *role models* of computer science are predominantly male, those who believe they can achieve something alike will equally be predominantly male.

According to psychologist Sylvia Beyer, the 'seeing is believing'-mechanism clearly manifests itself in the educational choices that female students have to make. Due to the low visibility of female engineers, "[women] tend to have low self-efficacy and believe they have little natural ability in male-dominated domains" [4, p. 156]. In other words, women do not believe that they would be successful in computer science courses,

and, therefore, they are more likely to engage in other subjects. In the light of this observation, the main purpose of Alice and Eve is to break the unfamiliarity toward female computer scientists; to demonstrate that they, too, are successful in the field. Eventually, these women must represent the female role models to whom current and future generations of female computer science students will look up to. In accordance, it is these generations that Alice and Eve hopes to attract: to draw aspirant female students towards the beauty of computing and to keep current students attached to it. Not by virtue of fair treatment, but by virtue of improving computer science.

2.1. EXHIBITION

The event itself has been split into two parts: an exhibition and a one-day symposium. It is especially through the former that the event's audience has become familiar with some of the pioneering women in computer science, such as Ada Lovelace and Margaret Hamilton. Nevertheless, the exhibition also displays women that are still very much active today; women whose contributions might not yet be widely known to the broader audience but are nonetheless of importance. Here, one must think of computer scientist Sanghamitra Bandyopadhyay, engaging in the complexity that is called evolutionary computation. Fortunately so, for, in 2014, Bandyopadhyay and her colleagues successfully identified a new genetic biomarker for breast cancer. It is especially women of the latter category that are closer to the students' own experience, rendering it easier for them to imagine and aspire to be in a similar position.

More concretely, the exhibition has been divided into two sections: a *booklet* [5] telling the tales of 25 women in computer science and a picturesque *banner presentation* telling the same stories more visually. Notably, both the selection of women and the selection procedure have been diverse. Here, the achievements of some pioneering women were brilliantly contextualized in historian Walter Isaacson's *The Innovators* [6], but the inclusion of most of the women was suggested through popular media articles. As it seems, the call for recognition is increasingly growing stronger. In the end, a list of almost 100 female computer scientists was narrowed down to a total of 25. This process was guided by the need for diversity on both a geographic level – covering different continents - and a temporal level - the 19th, 20th and 21st century. Especially related to the former, the event aims to provide role models for *all* female students, not only the ones originating from the Anglosphere.

2.2. SYMPOSIUM

The exhibition was first opened at the event's one-day *symposium*, an intellectually rich forum inspired by the United Kingdom's Lovelace Colloquium. At the symposium, presentations were arranged through which prominent female computer scientists could share insights from their research. Anna Sperotto, for example, elaborated on the dangers

of 'Denial of Service'-attacks. The symposium's main objective was to demonstrate - and proudly so - what women in the field were able to achieve. As co-organizer Mariëlle Stoelinga nicely summarized: "[it] is our deliberate aim to not address gender issues within computing, but rather to show that research done by women is simply relevant, interesting and excellent" [7]. As such, the symposium provided a space in which audience members could interact directly with their female role models. Aside from these presentations, female attendees active in the field had been asked to participate in a poster presentation competition rewardable with an encouraging prize.

Importantly, it must be observed that the overall set-up of the event - including both the exhibition and the symposium - can be extrapolated to adjoining engineering fields that are experiencing a similar gender imbalance, such as electrical and civil engineering. In those fields, many female breakthroughs are as unknown as those of female computer scientists. In order to both spur enthusiasm for follow-up editions of the Alice and Eve-event and to inspire other disciplines to undertake similar initiatives, information is disseminated through a website [8] and a promotional video. On top of that, the entire event has been documented through means of photographs.

3. RESULTS

Overall, the event received mostly critical acclaim from the nearly 100 attendees. As formulated on Twitter by Ph.D. candidate Judith van Stegeren, "[to] people who say "there's just no women in computing": you're wrong! We're right here, at Alice and Eve 2020. [...] We exist" [9]. On top of that, the conference booklet itself has already been widely disseminated, both online and through physical copies. Responses have been positive throughout. Notably, the optimistic appraisal experienced has been prompting ambitious follow-up plans. Although the event premiered at the University of Twente, plans either have been made or are in the making to have it organized at other venues as well. In March of 2020, the exhibition was supposed to embark on a tour across The Netherlands, visiting different universities and research institutes. The exhibition was equally supposed to premiere at NWO's yearly scientific symposium ICT.Open. Due to the COVID-19 crisis, though, these plans have been postponed. Next year, when the event gets organized at the Radboud University of Nijmegen, the organization equally wishes to expand its content with the inclusion of more female computer scientists. Moreover, the organization is looking into the possibilities of attracting a more international audience; it plans to have the Alice and Eve-event premiere at universities outside of The Netherlands as well. For now, a digital version of the poster exhibition is under development.

4. SUMMARY AND ACKNOWLEDGEMENTS

In the best interest of computer science, diversity among its practitioners is needed. In the light of this given, it is unfortunate that the field is significantly underrepresented by female students, for they, too, contribute to this diversity. Responding to this imbalance is the Alice and Eve-event. Through both an exhibition and a symposium, the event wishes to celebrate the female contributions to computer science. As such, it provides the future generation of female

students with role models; providing them with the motivation and aspiration needed to enlist to a similar computer science path. The event has been met with critical acclaim and follow-up plans are currently under development.

Finally, the organization wishes to extend its special thanks to Puck Kemper, who has created the imagery that has become the face of the event. On top of that, the organization wishes to show its appreciation to Jan van der Veen. His continuous support has prompted the writing of this paper. Last but not least, the organization must thank the event's many sponsors for bringing it into realization. For a complete list, please have a look at [5].

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INDUSTRY-LINKED PROJECT WORK: INTERDISCIPLINARITY WITH DESIGN, ENGINEERING AND MANAGEMENT STUDENTS

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Keywords: *Interdisciplinarity, project-based learning, challenges, engineering education.*

ABSTRACT

Interdisciplinary education has become a universal trend and a staple feature on most university's curricula. Its propensity for interaction among disciplines, purportedly endows students with the skills to tackle complex societal issues that haunt our modern society. A mixed-method study was undertaken to describe the challenges faced by both teachers and students in a second-year bachelor module at the University of Twente. The 15 European credits module funnels three separate tracks: Industrial Design Engineering, Mechanical Engineering and Industrial Engineering Management into an authentic industrial project. Its aim is to foster substantial input from all three specialities in order to solve the proposed problem, and to meet the set learning objectives.
Three issues for students were investigated, (1) communication issues, (2) teamwork problems and (3) prejudices held against the other disciplines. Half of the groups experienced communication issues magnified by the interdisciplinary situation, teamwork issues were present, but were mostly generic and therefore could not be pinned to the interdisciplinary situation alone. Finally, prejudice against disciplines and the feeling of being judged for belonging to a certain discipline was high. Interestingly, the students did not feel that the prejudices inhibited the ability for the team to work together. Teacher challenges included high student numbers and the ripple effects thereof, i.e. time constraints, finding suitable learning spaces, sufficient tutors, etc. These contextual pressures appear to be in direct contrast to the espoused policies of the university. Recommendations on how to mediate some of the issues, such as vigilant alignment of policies to practise and reduction of interdisciplinary knowledge gaps are offered.

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1 INTRODUCTION

Interdisciplinary (ID) education aims to develop essential 21st century knowledge, skills and attitudes (KSA) that students can apply later, in their future professional lives (Repko, Szostak, & Buchberger, 2017). Usually, these KSA's are fostered through collaborative project-based learning (PjBL) situations, thus exposing students to authentic interactions with a variety of parties and contexts. The challenges can originate from design obstacles inherent within the module, or from interpersonal complications that accompany most groupwork.

Three challenges, that could arise within an interdisciplinary project context, were used as focus for this study. They were generated through a collation of conclusions drawn from Adams (2007), Repko & Szostak (2017), and Borrego et al. (2013). The possible challenges include: communication problems, the presence of prejudice, and teamwork issues. These issues may have the potential to hinder effective learning and goal attainment. Design obstacles of the module could include suitability of the combination of student tracks or a weak integrated approach from the educators or students (Jacob, 2014).

2 METHODOLOGY

2.1 Case study setting

The research is a single case descriptive study. It explores the outcomes of the student experience of the interdisciplinary module 'Product Design Consumer Products'. Each year a different company is invited to define a design challenge. It is a mixed-method approach, with a qualitative and quantitative component. Specifically; student surveys, academic staff interviews and document analysis.

2.2 Case study details, instruments and sources

Participants: The module is fed by three separate tracks (360 students in total, ratio male/female is 3:1). Twelve academic staff were interviewed personally (semi-structured).
Instrumentation: A digital survey was sent to all students electronically and was estimated to take approximately 7 minutes. A total of 70 students responded (ratio m/f is 45/25). The survey consists 12 closed questions (Likert scales), and six open questions to gather detailed insights into the students' personal experiences. The closed section of the survey, to gauge value perceptions of ID, bias and communication levels within teams, was based upon parts of the Interprofessional Attitudes Scale (IPAS) (Norris, et.al 2015) and the Interdisciplinary Project Management Questionnaire (IPMQ) (Tormey & Laperrouza, 2019).
Data Analysis: Data from both surveys and interviews were processed and themed. Document analysis was undertaken from sources such as governmental publications and the University of Twente's own educational policy documentation.

3 RESULTS

Student Challenges. (*n*=70) *Personal prejudices*: approximately 80% of students admit to feeling (59) and projecting (54) prejudice from or against other disciplines. Interestingly though, 89% (61) were neutral or denied that the prejudices negatively impacted their ability to work together optimally. Of the communication issues that were present, 80% are related to ID (see *Table 1*). Teamwork is less so, with only 23% identifying a truly ID issue (see *Table 2*).

Table 1. Communication anecdotes reported by 33 students, those marked with asterisks are ID.

Categories of answers	Number	Percentage
Discipline-specific homonyms confusing*	12	37%
Perspective taking difficulties*	8	24%
Knowledge gaps*	6	18%
Quality of work (expectations)	5	15%
"Yes" but no further explanation	2	6%

Examples of comments about ID communication issues from the students:

Mechanical engineering student: "Yes, there was a discussion about the colour foam to be used for a model. I participated in this discussion, only to find out later that the colour of foam specifies hardness and is not about appearance."

Industrial engineering student: "Yes, when a concept or mechanism needed to be explained, there were sometimes misunderstanding because not everybody has the same vocabulary as the IDE people for example."

Table 2. Teamwork and other collaboration related anecdotes reported by 40 students.

Categories of answers	Number	Percentage
Scheduling and meeting issues (Design issue)	11	28%
Knowledge gaps hindering progress (ID Teamwork issue)	9	23%
Complaints about Management students' lack of role (Design issue)	8	20%
Differences in tackling the project (Teamwork issue)	7	18%
Unequal distribution of work (Design & Teamwork issue)	5	13%

Examples of comments about ID teamwork issues from the students:

Industrial design engineering student: "Some people are not willing to change their approach to designing a product, because they think their way is the best and most efficient."

Industrial engineering management student: "Yes, sometimes it was hard to understand all the topics, because you do not have previous knowledge. IEM students almost have no knowledge about any of the topics, so that sometimes was a problem."

Module Challenges. Academic staff issues are concerned with high student numbers and it was found that the problem is in direct contrast to espoused values of the university, i.e. small-scale education. Furthermore, there is a challenge in equally

allocating roles to all three tracks within the project. This was flagged by both teachers and students, and is complicated further due to the module's origins.

4 CONCLUSIONS & DISCUSSION

Student Challenges. *Prejudice***.** MacMynowski (2007) posits that prejudice within a team, can have a negative impact on collaboration. The majority of students projected and felt prejudice, however, it did not affect their ability to get on with the task at hand. The motivational perspective on cooperative learning may explain this outcome. According to Slavin (1995), cooperative incentive structures, here the group project, means that the only way students can reach their own goals is through the group being successful. So, this "need to reach their goals", may explain how they can get on with the project-work, despite having feelings of prejudice towards one another. However, we should be cognisant of the fact that there is no way to measure the quality of the project, if prejudice had not been present.
*Communication***.** Of the communication issues that were mentioned by just under half of the students, a high proportion were ID in nature. The motivation of the student to expend effort on appreciating the other disciplines' vocabulary, methods, perspectives, etc. is personal. Ariani (2013) posits that dispositional factors such as personality, can play a role in motivation and performance. Thus, certain students may need to be motivated and supported to take a more active role in their own student-led ID education; investing time and energy in seeking elementary information on their fellow discipline's KSAs. Formally instructing students on how to think from different perspectives, providing good examples of standards of work with accompanying rubrics to quantify expected levels, as well as training on introspection and reflection should help to alleviate some of the issues listed in *Table 1*. *Teamwork.* Of all the collaboration problems mentioned by students, only 23% were solely ID related (knowledge gaps). The rest of the complaints were either design based or generic teamwork issues. This may indicate that the ID dynamic does not have a large effect on basic teamwork when comparing mono-disciplinary and interdisciplinary groups. An opportunity to pre-emptively focus on knowledge gaps between disciplines, at the early stages of the team formation, presents itself. For example, creating an online resource where the fundamentals of the contributing tracks are outlined, and actively encouraging the development of life-long learning skills in students through the promotion of ownership. This could mediate some of the negative consequences of ID ignorance within a group. Taking steps to combine disciplines is primarily a social process, where individuals must communicate and interact often within disparate environments, ideas and bodies of knowledge (Holley, 2009). The unavoidable factor here are the individuals that make up a team. Personality may explain why some teams work well together and others not, therefore this may indicate that ID differences may show less of an effect on the project outcomes than the personality differences within a team.

Module Challenges. Rising student numbers is placing added pressure on the time of staff and resources of the university. This rise in numbers is due to the national stimulation of engineering education and expansion of the university through internationalisation. It is in direct contrast to the university's espoused values of "small scale education." Formal and documented alignment of administrative

expectations with the realities of academic staff is imperative to continue quality education and the safety of personnel. Furthermore, the design issues with regard to epistemological sovereignty of one of the tracks (Healy, 2003) is proving to be a recurring theme when feedback is received from students. One of the tracks continues to struggle to contribute meaningfully to the project. Iterations are implemented annually to attempt to mitigate this, however selecting a more suitable project (for all three tracks) seems the most direct path to resolution of this imbalance. Creating a check list of criteria applicable for all three tracks within a project, will in the very least, eliminate unsuitable project initiations.

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CITIZEN ENGINEER - ENGINEERING STUDENTS' MOTIVATION TOWARDS AN ENGINEERING CAREER

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ABSTRACT

This study asks 427 engineering students about their motivation for becoming engineers. It is centered around the course "Introduction to the engineering profession", that incorporate some Bildung-related topics. The data suggests that intrinsic motivations connecting to the engineering profession were common, and that many students have the prospect of building, creating or developing as a central motivational factor. The paper suggests using this as a starting point to raise perspectives of engineers as builders also of society and incorporating discussions around the societal role of an engineer. This seems the most fruitful way to dip into the intrinsic motivation of the engineering students when teaching Bildung-oriented topics where they themselves may not immediately see the connection to their role as engineers in the making.

1 INTRODUCTION

Engineers used to be perceived as designers of both actual artefacts and of a prosperous society [1, 2]. Today, the public perception of engineers is perhaps more vague [3]. However, engineers seem to be likened with scientists in the sense that they provide solutions to problems by 'applying' a strong sense of rationality and scientific methods [4]. This perception disregards the fact that engineers provide solutions which serve human needs [5]. It also disregards a realisation that has been emerging during the last twenty years – that solutions to problems in the real world requires a holistic approach [6]. These two points imply that engineers would need to understand their roles as engineers in order to cooperate with other professions, and

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also to appreciate the non-technological aspects which often comprise a solution to a problem.

In a broad sense, these topics could be connected to engineering Bildung, understood as a process enabling you to become a *citizen* – an active participant in society, and not simply a vocational practitioner of a craft. This idea is found in both the tradition of classical Bildung and the Anglo-American tradition of liberal education [7-9]. This also explains why some see science and technology as relatively less relevant to Bildung, as many other fields, like the humanities and the social sciences, directly research aspects of society.

All engineering students in Norway take a 10 ECTS-credit course during their first semester – "Introduction to the Engineering Profession", which contains topics related to engineering Bildung. The first author has been central in developing this course, and has written a textbook in history of science and technology, scientific methods and ethics to cover the course [10].

Earlier experiences with this course have been mixed. The students' expectations of "usefulness" connected to their professional identity as budding engineers seem to collide with the more Bildung-oriented topics of the course [11]. The aim of this paper is thus to discuss how one could address the students' initial lack of interest in the non-technical topics within the course in question, by answering the following research questions:

1. What are the motivations of engineering students?
2. How can this knowledge be used to engage students in Bildung-related educational topics?

2 A BRIEF GLANCE AT MOTIVATION

It is common to divide motivation into intrinsic and extrinsic motivation. The prior motivation is connected to the joy you get from the task itself; the latter is connected to some form of external reward. A similar affective variable, interest, has been shown to be connected to intrinsic motivation [12].

Several studies over time within different fields have shown that while intrinsic motivation is very positively correlated with better quality work and better performance, a focus on extrinsic rewards may be counterproductive [13-16].

3 METHODICAL CONSIDERATIONS

The university in question is distributed among four campi across Norway, and during the 2019 fall semester the first author was responsible for teaching the introductory part of the course. In total, about 1100 first year engineering students were registered for the course, from all engineering programs and across the four campi.

The students in question all participated in the course "Introduction to the Engineering Profession" during the fall semester of 2019. They were asked to answer in open text "Why do you want to become an engineer?". In total there were 427 respondents, divided on 4 campi (see table 1).

In analyzing the data, we will use thematic analysis as a method, as discussed by Braun and Clarke [17], searching for recurring themes or patterns within the data, and organizing and interpreting these patterns.

The analysis will be theoretical in the sense that it will make use of the categories of intrinsic and extrinsic motivation, but within these categories the search for themes will be inductive.

4 RESULTS

The analysis yields a plurality of motivations that can be divided into intrinsic motivations and extrinsic motivations. The data can however also be divided into personal motivations (what the education can do/does for me) and more societal motivations (environment, contribute to technological development etc.). In Table 1 we extract the societal motivations into a separate theme of motivation named “Altruistic” in addition to the themes intrinsic and extrinsic motivation.

Table 1: Responses to "Why do you want to become an engineer?" categorized by type of motivation, by campi and total.

Motivation	Campus 1 (N=176)	Campus 2 (N=101)	Campus 3 (N=46)	Campus 4 (N=104)	Total (N=427)
Intrinsic	116 (66%)	66 (65%)	34 (74%)	70 (67%)	286 (67%)
Extrinsic	58 (33%)	34 (34%)	14 (30%)	34 (33%)	140 (33%)
Altruistic	62 (35%)	20 (20%)	8 (17%)	21 (20%)	107 (25%)

We see that the results, with one exception, are similar across the campi. First of all, many students have answers that fit several categories. They are naturally not exclusive, and many are motivated by e.g. a job that is both interesting and well paid.

Around 2/3 of the students express intrinsic motivations - a personal interest in engineering. We can however see variation within this group. Some students are more interested in the type of work they will be able to do as an engineer after finishing their education. Others express interest in the education in itself. When it comes to exploring this intrinsic motivation further, we see that 1/3 of the students in expressing their intrinsic motivation explicitly mentions building, creating or developing things. The idea of creating seems to be at the core of the motivation of many engineering students. Another subject that appears relatively often in the short open-text answers is the opportunity to combine the theory and praxis in different ways. 1/10th explicitly mentions this as part of their intrinsic motivation for engineering.

Within the category of extrinsic motivations, a good job market, a well-paid job, and a job that brings social status are recurring themes within the 1/3 of students that promote this as a reason for becoming an engineer.

Finally 1/4th of students explicitly expresses a wish to contribute to society as an important motivation for becoming an engineer.

Within a dichotomy of intrinsic/extrinsic motivation the altruistic contribution to society must also be considered an intrinsic motivation, but as a motivation for improving the world rather than a more direct interest in the topics. Adding all

respondents that have registered either intrinsic or altruistic or both as motivations we get that a total of 89% of engineering students according to themselves are driven at least in part by some form of intrinsic motivation. Less than 11% are driven solely of extrinsic motivations.

5 DISCUSSION AND SUMMARY

From the results we can identify how 9/10^{ths} of engineering students reports having different forms of intrinsic motivations for studying engineering. As intrinsic motivations have shown to consistently provide better results than extrinsic motivation this should be good news.

However, an intrinsic motivation for becoming an engineer, does not necessarily mean that the students have an intrinsic motivation for this “Introduction to the engineering profession” course. Much of their intrinsic motivation is connected to the job as an engineer - the engineering profession. This is also in line with the referred previous research [11]. It would follow that an important success factor for the Bildung-related topics about different aspects of society is to connect them to the engineering profession.

To further this discussion, we must also look closer into the responses to see where such connections could be made for the overarching subjects of the course, and to promote a Bildung-oriented engineering education. In analyzing the prominent focus on developing, creating etc. in the students’ motivation for becoming an engineer one might ask the question: Could the key to *Bildung* for engineers be in *building*? Their motivation for building and creating could be understood as both building a machine or a structure, and as (contributing to) building a society.
As part of the course is about history of technology it thus makes sense to teach this aspect of the history of the engineering profession and promote critical discussions around the contributions to society of different professions historically, and in the present.

There are very few aspects of our society that are untouched by technology, and in extension, by the engineering profession. This should enable teaching Bildung-oriented topics to engineering students on the basis of their professional identity of engineers. Based on the data from this survey, this seems like a promising path towards adressing the perceived lack of “usefulness” some teachers struggle with in this and similar topics.

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INTERDISCIPLINARY TEAMWORK AS A BASIS FOR INNOVATION COMPETENCES DEVELOPMENT

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Future engineering skills and talent management.
Keywords: *interdisciplinary, work-oriented learning, innovation, pedagogy*

ABSTRACT

Experts such as engineers in contemporary, global context often work in teams with members from various areas of expertise and professional backgrounds in order to develop new innovative products and services. That is why new training methods with an interdisciplinary approach are increasingly needed and developed. Our paper presents how we developed an interdisciplinary, work-oriented learning project over the years 2014-2017 and what results we got. We aim to provide pedagogical insights on how to support the development of innovation competences. The learning project was originally implemented in the degree programs of engineering and international business at Vamk in Finland. In addition, we compare these results with current experiences received during years 2018-2020, when a similar cross-disciplinary, work-oriented learning project has been implemented at Seamk in Finland.

An interdisciplinary approach means that people work together as a team, presenting their own field of expertise and integrating each other's professional perspectives. Interdisciplinary teams develop individual and collective decision-making and help team members to understand and appreciate other disciplines.

Findings of these qualitative learning experiments will be presented. Conclusions as to integrate diversity management at the university level and suggestions for the development of the engineering curriculum will be provided. Practical tips for teachers organizing interdisciplinary learning projects will be given.

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1 INTRODUCTION

In the present era, an increasing number of companies are hiring not only deeply skilled specialists but also experts who are skilled to work in interdisciplinary teams. In the near future, organizations are emphasizing interpersonal, cognitive and systems thinking skills in their recruitment [1]. More specifically, these interdisciplinary experts are expected to carry and develop metaskills of networking, critical thinking and team leadership [2]. In order to match with these skills of future employees, new educational methods are needed where interdisciplinary approach is used as a pedagogical core. Often, the literature on interdisciplinary collaboration seems to be focused on the sociocultural aspects, for instance, how social interaction is developed and supported in interdisciplinary context. However, interdisciplinarity should not be narrowed to the coordination of various tasks, but a specific attention should be put on how skills and knowledge can be transferred across boundaries. [3]. This is where our paper aims to contribute by describing how interdisciplinary learning supports and enhances the interdisciplinary cohesion and transfer of innovation competences.In addition, we consider design thinking as a value-adding educational tool, by which teachers can not only support practice-oriented learning of students but also through which teachers can transfer innovation competences to be used in pedagogical development.

2 METHODOLOGY AND ANALYSIS

We base our analysis on the methodological process of design thinking through which we as an interdisciplinary teacher team defined, developed and implemented interdisciplinary, work-oriented learning projects at two universities of applied sciences in Finland (Vamk and Seamk).

2.1 Project-based learning combined with design thinking

In general, project-based learning is based on cases provided by companies, in order to give authentic tasks for the students to solve open-ended problems in a cooperative context. Real world business projects and cases are very often emphasized in studies at universities of applied sciences. Project-based learning can be seen to have various, positive impacts, for instance, on skills related to reflection and interaction as well as critical thinking and problem-solving proficiencies. Still, project-based learning often is implemented within rather than across sectors. For example, technology students implement a technology-related project, rather than a project, where the main emphasis is on building new business models. On the other hand, when there is an interdisciplinary project, it might be difficult to find a company which gives a problem defined from various professional perspectives. [4]

In order to tackle these type of expectations, needs and challenges, we have combined an interdisciplinary and design thinking approach when planning and implementing our learning projects. The following figure illustrates our design process, which starts by discovering what are our possibilities, defining the design and contents of learning, implementing the learning project and finally reflecting the experiences and results.

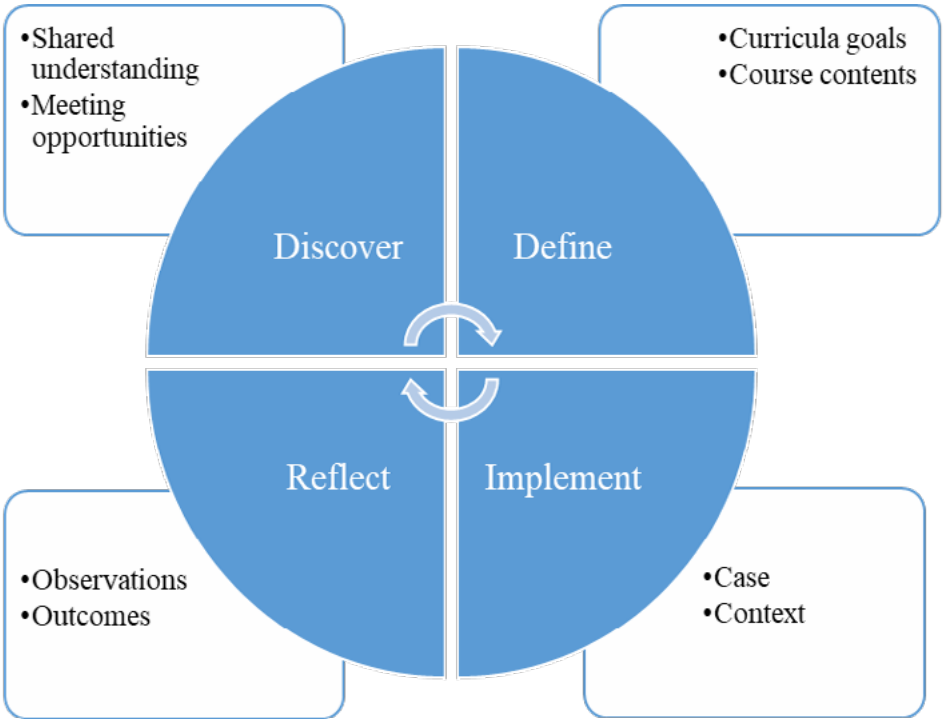

Fig. 1. Design Thinking Process Used in Planning and Implementation

2.2 Discovering collaborational possibilities

When starting to plan an interdisciplinary approach, it is vital to build a ground for shared understanding, as for instance studies in collaborative design and design thinking suggest [5]. The planning phase for our interdisciplinary learning project might not have started without an EU funded project, in which we together with several European partners developed a multi-sectoral learning environment for creativity. In addition, one of us participated an EU IP programme, where also international partners interested in similar approach were found.

To create shared understanding, we as teachers needed these meeting opportunities, based on which common interests could be identified. We had several discussions on requirements for future employees in our fields and what type of holistic understanding is required by the competitive and complex business environment. We realized that as well as companies aim towards continuous, open innovation across industries, we also as teachers should develop an open, learning platform for students to learn collaboration and to establish shared understanding across different study fields.

2.3 Defining the course design

When we had shared a common understanding of the requirements and possibilities of a joint interdisciplinary learning project, we started designing how to implement our idea in practice. We can distinguish between intended, implemented and attained curriculum. The intended curriculum refers to the written and formal curriculum, the implemented curriculum refers to the operational curriculum perceived and used by teachers in the classroom and attained curriculum means the learning experiences perceived by the students [6].

Since the intended curriculum was not going to be revised, we had to determine which existing courses could be integrated into the project. We had to review and decide the operational curriculum: which current courses could be used so that the course content and learning objectives apply to interdisciplinary project learning. In addition, course schedules required joint planning and flexibility, in order to match different study programmes together.

At the beginning, one of the main goals was to develop the innovation competences of engineering students with those of international business students. Later, when other study fields were also involved, we were keeping the same goal to develop students' creative and interdisciplinary competences. We realized that establishing not only interdisciplinary, but also multicultural teams could bring benefits like increased flexibility in problem solving, diversity of ideas and creative ways of thinking, and the development of personal, social and cognitive capabilities. We also decided that the joint project would be a one-week intensive course. This was not only a matter of operational decision, but also an acknowledged choice, as innovation projects often require experimental processes and intensive ways of working.

2.4 Implementation and activities compared

The first implementation in 2014 was a pilot course at Vamk where we tested our interdisciplinary learning approach. By collaborating with local companies, we created a presentation program where business experts, international partners and teachers provided insights on chosen topics. In addition to attending the presentation, the students were actively working for a five day period. We defined interdisciplinary and multicultural student teams (from engineering and international business programs) in advance, and we organized a half-day team meeting before the formal intensive week. When starting the intensive week, the teams received instructions for their team task: each team was expected to plan how to market a particular technical product or service in the country of their choice. So, the pilot project had not a single, specifically defined case for all teams, but teams had to define their product or service and the problem to be solved with it. As we were not able to pre-define their case, we were not able to define a precise model how to coach the teams in their tasks. However, we defined the process how they should approach their task, and this process model was a helpful tool for both teachers and students.

When planning our next implementation in 2015 at the same university, we considered our experiences from the previous year. First of all, we decided to collaborate closely with a local business. We selected an innovative SME as our partner and had meetings with them beforehand in order to create a mutual understanding how the project could be executed. This company instructed students to design how to bring their new energy related product concept to international markets. Otherwise, we followed the practices of the previous year. Coaching student teams was much more effective based on previous year's experiences.

The third implementation at Vamk in 2016 was based on the same SME company case. However, we changed the execution by involving a group of business students from a German university (HdWM in Mannheim), in addition to our students from

engineering and international business programs at Vamk. The case was further developed by increasing the challenges of internationalization for the task. In addition, we developed the schedule in order to create the best possible conditions for teamwork, supported by company visits and creative evening program.

In 2017, we travelled with our students (from Vamk`s engineering and internationl business programs) to Mannheim, Germany, where our partner university (HdWM) designed the intensive week program. They also negotiated with a local SME partner, which gave a very difficult project task for the students. The student teams had to plan how the company's current product range could create new collaborative relationships for the company in entirely new industries. A pedagogic aim was also to follow how team performance is affected by a more challenging goal, and how this affects the methods of communication and coaching.

During 2018, 2019 and 2020, a similar interdisciplinary approach has been adapted at Seamk in Finland. One of us has been acting as a coordinator for this learning project, which continues in the future as well and is implemented on a yearly basis. It is organized as an intensive week, and involves all, over 700 first-year students of Seamk. Students (from engineering, business and culture programs) are split into twelve groups each of which are coached by an interdisciplinary teacher team. In each of these groups, students form interdisciplinary teams of five to six students. Each group focuses on a specific company case, provided by local companies representing different industries. The given cases can focus on, for example, to innovate new customer segments for a current service or to innovate current product for new markets as well as to find new ideas for future business models. The pedagogic model is based on developing the students' innovation competences, supported by design thinking, service design methods and specific case objectives.

2.5 Findings on the innovation competences

After each learning project, we have analyzed student responses, based on both quantitative and qualitative research methods. The quantitative, short surveys, which the students have responded to, have had some variation in survey outline and questions each year. The comparison of the numerical results is not viable in this short paper, instead, we summarize student responses in qualitative manner. In conclusion, student reflections show that learning projects have brought more cultural awareness and developed their problem-solving, cognitive and innovation skills. Students also seem to evaluate they have developed both interpersonal skills as a team member and as their personal expertise in various subject areas. Also, their time management and presentation skills are perceived to be improved. In addition, not only open-minded teamwork, but also open-minded coaching seems to become more important when the diversity of students, professions and nationalities is increased.

Transfer of innovative competences in interdisciplinary project work can definitely include various factors which have to be carefully considered, as described in a specific student reflection: *"Working in an interdisciplinary team can easily feel like walking on thin ice – having to be extremely careful so that the surface won't crack."* In order to be able to innovate in an interdisciplinary team, you need to dig deeper into

the knowledge from different disciplines. As critical aspects related to innovation competences, students highlighted, for example, difficulties in understanding each other's ways of working and the challenges of defining common goals. We might assume that these difficulties are closely related to differences of perceptions and cognitions, which have also been studied by researchers from cognitive and cultural fields [7]. Your professional background affects how you perceive and understand the environment and context. The more similar you are with other people, the easier it might be to innovate together. However, transfer of innovative knowledge needs perceptual differences which can construct shared understanding more effectively. A particular student comment reflects this issue: *"I felt the other members did not understand my point of view, which was very frustrating. But I kept explaining, and finally, I think we started to look at the same direction. At least they said they understood my point of view…"*

In terms of innovation competences, interdisciplinarity might also be transferred to multipotentiality [8]. Instead of acting in a single, professional role in an interdisciplinary context, each person might need to educate themselves in multiple, cross-border skills and knowledge. This clearly poses a new possibility and challenge for interdisciplinary educational programmes: are we expected to educate, for instance, engineering versus business students separately or should we aim for new professionals with multiple focuses in their study path? As a student comment reflects: *"During this team work, I became interested in having some courses in engineering, although I have never thought myself to be interested in any technological studies. I will at least try to find out, if this is possible in my study programme."*

The model we followed when planning and executing our interdisciplinary study project integrated and benefited from design thinking process. We emphasize this model as one of our findings, which supports the development of innovation competences. Design thinking is especially beneficial when there is a wicked problem to be solved, which most often is the focal point in interdisplinary projects. In addition, following desing thinking made us to offer various visualization and ideational methods for the interdisciplinary teams to exploit and test.

3 CONCLUSIONS

The basis for interdisciplinary learning is the ability to be in relation to other learners, which requires effective networking and diversity management skills, and in particular intercultural skills in a global environment. Our results show that interdisciplinary and multicultural project learning environments develop metaskills needed for innovative behaviour, for instance, cultural knowledge, creative thinking, team leadership and planning skills. It can be suggested that higher education curricula should not only continue the existing interdisciplinary project courses but create new ones where students intensively learn collaborating across boarders and develop essential innovative competences for future professionalism.

Interdisciplinary teamwork develop both individual and collective problem-solving abilities and help to understand the added value provided by other disciplines. The basis for interdisciplinary learning is the ability to interact with other learners, which

requires interpersonal skills as well as understanding of diversity and cross-cultural perspectives and possibilities. When students from various disciplines build a shared understanding and responsibility, they can form an engaging and empowering relationship with one another.

To conclude, interdisciplinary innovation projects should be perceived as a method providing growth possibilities for universities, businesses and students. Research evidence from various countries shows that innovative collaboration of businesses and universities is beneficial for all parties, developing their innovation and knowledge management capacities. Companies get new ideas and systematic support for innovation, universities get in-depth knowledge of companies in the region and students strengthen their business relations as well as their practical skills [8]. Universities of applied sciences should not only train students to become experts in their specific sector, but helping them to become skilled in cross-sectoral and open innovation. By supporting the forming of new type of behaviour and attitude towards interdisciplinary innovation, universities can shape the future of their society.

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THE INFLUENCE OF THE SUSTAINABILITY AGENDA ON LEARNING OBJECTIVES IN INNOVATION COURSES FOR ENGINEERING STUDENTS?

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ABSTRACT

Sustainability is an increasingly important topic all over the world and engineers have an important role. This calls for a new generation of innovative engineers who contribute to solutions with sustainability awareness. But how can we educate for this? With this contribution, we wish to contribute to an emerging dialog about how to formulate learning objectives that incorporate sustainability in innovation courses. In theory, sustainability is a capacious term that can be discovered through numerous lenses. In our study we examine how the phenomenon of sustainability is described in theory and in practice. We aim to unfold the multiple dimensions of sustainability rather than identifying the dominant discourse. Our research is based on insights from literature and empirical data from course descriptions that incorporate sustainability in learning objectives for innovation courses in engineering education. Our results show that despite study programs ambition to incorporate sustainability into educations the translation from an overarching ideology into concrete assemble learning objectives is not completed. Learning objectives most often are centered “about” and “for” and only few on “how-to”/ “through” . We also see a focus on management and strategy rather than on finding solutions. Basic knowledge about higher level decision making, stategizing and business modeling in organisations is relevant, however the ability to create new solutions, i.e. entreprepreneurial competences, is paramount.

1 INTRODUCTION

1.1 Section 1

We can no longer not care - Our environment is beyond self-recovery [1]. This is the main driver for the prominent sustainability agenda, which is embodied through the UN Sustainable Development Goals (UN, u.d.) adopted in September 2015 as the most widely accepted agenda for sustainable development today [2]. The SDG’s provide a political framework for communication about contribution to sustainable development.

Higher education plays an important role in the context of sustainable development and has a significant influence on the way in which future generation of engineers will deal with the sustainable challenges [3]. Entrepreneurship and innovation can be the engine for transforming our world and overcome the diversity of the global sustainable challenges [4].
Even before the SDG's was launced in 2015, there was a focus on sustainability and how higher education could play an important role in sustainable development and about which competences were needed. [5] describe how all enginerering students at DTU must obtain a relevant level of competences for understanding sustainability and quatitatively assessment of sustainability with the focus on integrate Life Cycle Assessment (LCA) and life cycle thinkining in education. [5] suggest sustainability to be part of all study programmes starting with few courses at a bachelor level and then to progress into more courses at master level. With this progression the course content should become more complex as the curriculum progresses and with a higher level of Blooms taxonomy (knowledge, comprehension, application, analysis, synthesis and evaluation). [4] have summarized seven competences which are important for sustainable development; (1)systems-thinking, (2)foresight-thinking,(3) normative (values, principles and target for sustainability), (4)embracing diversity and inter-disciplinarity; (5)interpersonal, (6)action and (7)strategic management. In higher education these competences portrais similarities with competences associated with innovation and in theory these competences could serve as sustainability learning objectives. But what is done in practice to embed sustainability into engineering education?
In this study, we want to explore how sustainability is transferred into learning objectives used in the innovation courses for engineering students (BSc and MSc level) at three different universities in Denmark. One could refute that adhering to the sustainability agenda in engineering education goes beyond innovation courses. However it is decided to focus on these courses because they evolve around how to change current practice. We aim to unfold the multiple dimensions of sustainability rather than identifying the dominant discourse and therefore we will provide examples and not at complete mapping of all learning objectives. Our research is based on insights from empirical data from course descriptions that incorporate sustainability in learning objectives in the context of innovation courses. In this study we will focus on innovation course but it will also be relevant for other topic/courses. We look for patterns and qualify the learning objectives with regards to sustainability.

2 METHODOLOGY

2.1 Section 1

This study sets out to explore how sustainability in innovation is addressed in learning objectives at three different universities in Denmark. The learning objectives were collected based on an online search in the course databases using the search word "sustainable innovation". The inclusion criteria was only courses for engineering students. At one of the universities only courses that had sustainable

innovation in the course name were shown, the other two universities yielded all courses where sustainable and innovation was in the course description.
The searchs yield 147 courses across the three universities. The data is cleaned for duplets and only engineering courses are examined. 11 innovation courses were sampled with the purpose of having diversity. Seven courses are at master level and four are at bachelor of engineering level. Three of the courses are credited with 10 ECTS and eight are 5 ECTS courses. 105 learning objectives are identified. Out of these 56 are not specifically focusing on sustainability and are labeled "General learning objectives". These are grouped in themes. The remaining 49 learning objectives with a sustainability focus are selected for the further analysis. The learning objectives were sorted by learning *about*, *for* or *through* sustainable innovation.

3 RESULTS

Sustainability and awareness of climate changes have been part of the curriculum for engineering (innovation) courses for many years. The incorporation of sustainability into the courses have been done in many ways. Inspired by entrepreneurship education [6] the approach to teaching sustainability can be divided into education *about, for* or *through* sustainable innovation. The *about* approach is focused on acquiring theoretical knowledge about sustainability. Learning *for* sustainability can include applying tools, analysing and evaluating solutions. Finally learning " through" sustainability is about developing sustainability competences in expirence based learning designs, where the students learn to develop solutions/opportunies by themself.
In the folloving sections the findings are presented, first with a focus on general learning objectives (Table 1) and then the sustainability learning objectives (Table 2). Out of the 11 sampled courses four had a major focus on sustainability, more than half of the learning objectives for the course included sustainability. The rest had half or less of the learning goals, down to one, centered on sustainability. This testify to the fact that in practice the emphasis on sustainability in learning objectives varies on a broad spectre. The courses represent different levels (BSc and MSc), however explicit signs of progression was not detected as [5] recommened. Moreover, it also varies how these learning objectives are acquired. One course explicits gaining practical work experience and participation in experimental setup work, while other courses articulates groupwork, stakeholder interaction, prototyping, testing and simulations as methods to developing knowledge, skills and competences.

In the next two sections examples of the general learning objectives and the sustainability learning are presented.

3.1 General learning objectives

The general learning objectives (Table 1) reflect the context in which the sustainability is embedded. Some courses have a diciplin specific focus i.e. biotech or aquatic ressources. Learning objectives, which relate to higher level of decision

making such as strategy, management, business modelling and business planning, are also constitute to a context. Other courses focus on the design process of sustainable solutions and some go into production specifics.

Table 1. Examples of general learning objectives categorised according to topic

Topic	Examples of learning objectives
Discipline Specific contexts	• Describe a biotechnological production company with respect to substrates, organisms and processes
Management and strategy	• Knowledge about the role of management and humans in intelligent production.
Business models/ planning	• Define a value proposition using methods in innovation and business development
Design and production	• Perform detailed design and analysis of the selected solution
Entrepreneurship	• Evaluate the business opportunity with potential users and customers and argue for actions and choices taken based on the evaluation

Finally, entrepreneurship is also seen as a context, where sustainability is embedded into the process and to creation of new ventures.

3.2 Learning *about, for* and *through* sustainable innovation

The sustainability specific learning objectives can be divided into learning *about, for* and *through* sustainability. Learning *about* sustainability relates to theoretical knowledge on the topic, examples of popular topics can be found in Table 2.

Table 2. Learning objectives divided into learning about, for or through

Category	Examples of learning objectives
Learning About	• Demonstrate knowledge on different theories learned throughout the classes such as: Depletion of natural resources, Eco-design, Life-cycle assessment, Sustainable Development Goals, Circular Economy, Cradle to cradle, scares ressources, overexploitation • Explain the broad meaning of sustainability (environmental, social and economic
Learning For	• Evaluate environmental performance using the life cycle assessment framework • Model and interpret multi-criteria decision-making problems in sustainable design • Criticize and assess the strengths and weaknesses of approaches for sustainable design • Must have the competencies to apply principles of agile and sustainable production to company cases and design intelligent production and service systems

	• Perform an analysis of "governance" and development of regulation and legislation within the field, and discuss social and environmental advantages and risks of the new technology, and relate to examples of these aspects
Learning Through	• Apply entrepreneurial methods and processes to develop a sustainable business opportunity based on the defined problem.

Learning *for* sustainability includes a variety of process tools and analytical tools that can be used to access solutions on different sustainability parameters. Learning *through* sustainable innovation include learning goals that requires action/expirenece based learning [7]. These learning goals are complex to design for and require that students move from thought to action and reflection. Each mode (about, for or through) are not mutualy exclusive, on the contrary they compliment each other and can be found in a mix in learning designs.

4 DISCUSSION AND SUMMARY

The learning objectives that belong to the category “about” can be categorised as knowledge reproduction on the levels of remember and understand, and are at the lower level of Blooms taxonomy. On the next levels learning “for” relates to applying tools, analysing and evaluating solutions. Only learning “through” sustainability reaches Blooms top level, create, where learners combine parts to make a new whole. Experiences from entrepreneurship education show that this the way of learning is challenging for both educators and students but also highly effective in terms of influencing behavioural intent [8], [9].

[4] highlighted the relationship between innovation/entrepreneurship and sustainable and mentioned the following as important for both: complex problems, the importance of novelty, the importance of self-involvement and the engagement with others. The learning objectives reported in this study showed the same pattern. But we also see a focus on management and strategy rather then on finding with solutions. The focus on management and strategy which could be the first way to go, but the future engineer is expected to be able to solve the challenges and make solutions, thus more action and focus on implement and operate have to be taken. Given the unique potential for engineers as solution makers, one could argue that basic knowledge about higher level decision making, stategizing and business modeling in organisations is relevant, however the ability to create new solutions, i.e. entreprepreneurial competences, is paramount.

In extention the context dependency of innovation and entrepreneurship [10], [11] also makes learning objectives related to the disciplinespecific context essential. Out of the seven competences [4] have summarized which are important for sustainable development, the major focus seems to be on strategic management, systems-thinking, foresight-thinking, normative and interpersonal competences. There is only a minor or no focus on embracing diversity, inter-disciplinarity and

action. This could give food for thought for next generation of development of sustainable innovation learning goals for teaching practice.

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Appendix 1: Tabel 1 extented

Topic	Examples of learning objectives
Discipline Specific contexts	• Describe a biotechnological production company with respect to substrates, organisms and processes • Evaluate the potential for biotech development in different Cultural and geographical contexts • Discuss regulatory constraints on bio-production. • Emerging tech • Aquatic ressources
Management and strategy	knowledge about the role of management and humans in intelligent production. •Create a plan for organization and operation of the business •Suggest strategies for innovation. • •Judge the economic potential of an innovation
Business models/ planning	• Define a value proposition using methods in innovation and business development •Create an economic assessment of the business •Create a plan for organization and operation of the business •Create a business plan
Design and production	-Perform detailed design and analysis of the selected solution •Account for patent issues
Entrepreneurship	- Identify and collaborate with relevant stakeholders inside and outside the university to develop the business opportunity -Evaluate the business opportunity with potential users and customers and argue for actions and choices taken based on the evaluation -Make a realistic budget for the business -Pitch a business opportunity

Apendix 2: Table 2 extented

Category	**Examples of learning objectives**
Learning About	• Demonstrate knowledge on different theories learned throughout the classes such as: Depletion of natural resources, Eco-design, Life-cycle assessment, Sustainable Development Goals, Circular Economy, Cradle to cradle, scares ressources, overexploitation • Explain the broad meaning of sustainability (environmental, social and economic
Learning For	• Evaluate environmental performance using the life cycle assessment framework • Apply theories, methods, and tools for sustainable design of product and production systems to real-world problems • Model and interpret multi-criteria decision-making problems in sustainable design • Criticize and assess the strengths and weaknesses of approaches for sustainable design • Evaluate the sustainability of the production by means of a life-cycle analysis • Must have the competencies to apply principles of agile and sustainable production to company cases and design intelligent production and service systems • Perform a life cycle check of the technology and analyse paths for environmental optimisation of this a.o. collect new information and perform a basic life cycle screening of the technology in relation to competing options • Perform an analysis of "governance" and development of regulation and legislation within the field, and discuss social and environmental advantages and risks of the new technology, and relate to examples of these aspects
Learning Through	• Apply entrepreneurial methods and processes to develop a sustainable business opportunity based on the defined problem.

ETHICAL REFLECTION OR CRITICAL THINKING? OVERLAPPING COMPETENCIES IN ENGINEERING ETHICS EDUCATION

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Keywords: *critical thinking, ethical reflection, engineering ethics, case-based exercises*

Abstract
Ethical reflection is considered to be an important competency for engineering ethics education. However it has no clear definition, which makes it difficult to effectively incorporate it into engineering ethics education. This paper proposes an operationalisation of ethical reflection into four learning goals which can help educators explicitly and systematically assess ethical reflection when using case-based exercises in the engineering ethics classroom. The four components were adapted from established educational approaches for critical thinking and then expanded to apply to normative propositions, the specific domain of ethical reflection.

1. INTRODUCTION

Educating engineers for the challenges of the 21st century should include not just technical skills, but also societal and ethical competencies [1]. One of the major ethical competencies is the ethical reflection, understood as a process in which (future) engineers can "reflect on the ethically relevant choices they make during the design process (…) [and] take into account all relevant moral values" [2]. However, ethical reflection is often difficult to teach because it has not been sufficiently defined and operationalised to distinguish it from other forms of thinking. Since ethical reflection is an under-determined concept in education, it becomes hard to operationalise for in education the classroom. In this paper, I propose a way of operationalising it for engineering ethics education by drawing inspiration from a similar yet distinct competency, namely Critical Thinking (CT).

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2. CRITICAL THINKING AND ETHICAL REFLECTION

CT is one of the highest educational competencies, usually defined as a form of “reasonable, reflective thinking focused on deciding what to believe or do” [3]. In engineering education, CT is predominantly understood as a problem-solving skill [4], hence taught as a cognitive skill-set – as seen, for example, in the ENAEE (the European Network for Accreditation of Engineering Education) framework. While CT relies on many cognitive skills such as “reasoning, knowledge, problem-solving and decision-making" [5] it is conceptually distinct from these skills which are necessary but not sufficient conditions for being a critical thinker [6]. Thus, ‘critical’ is the characterisation of the process itself, not of the outcome of the judgement. CT is not just about being logical in one’s practical judgements or arriving at a correct answer, but about being careful, taking as many different aspects as possible into consideration, while also being sensitive to one’s own cognitive biases.

In contrast to CT, ethical reflection is more vaguely articulated as competency in engineering education. Conceptually, ethical reflection remains underdetermined because it is usually assumed that everyone already knows what reflection is [7] hence ethical reflection should not be that different. It is usually mentioned as a competency belonging to “moral decision-making skills” [8]. Ethical reflection implicitly contains some form of critical engagement because the student needs to show that “the actual existing way of dealing with moral issues is not taken for granted” [2]. It has been argued that ethical reflection is incomplete without a critical stance because it can fall into common pitfalls such as "moral intolerance, self-deception, and uncritical conformity"[9]. When students engage in ethical reflection, they do not merely apply an ethical framework to the case at hand, nor do they look for common ways of dealing with the situation, but question the very assumptions in the common approaches.

Ethical reflection uses an overall critical approach in its processes, such as questioning the very premises from which one builds moral knowledge, including the cultural and religious foundations of norms, values and practices. Therefore it makes sense to use some of the pedagogical approaches for CT to teach ethical reflection but with an adjustment: CT and ethical reflection overlap in some methods, but are not identical. The main difference concerns the types of propositions to be assessed. CT is considered a form of ‘scientific thinking’ in real life hence it works best when the propositions evaluated can be examined for evidence; descriptive propositions are the best fit. Meanwhile, normative propositions pose a challenge for standard CT. Some evaluative proposition could be evaluated using CT – for example “The instrument X is better than Y” - but not all evaluative propositions are fit for this approach (for example

"America is the greatest country in the world"). Similarly, prescriptive propositions ("We should make America great again!") cannot be assessed via standard CT. In these cases, ethical reflection entails that students evaluate the meanings of the normative terms (greatness in our case) and their cultural, social and historical background, finding some frame of reference. While CT uses objectivity as the ultimate criteria for evaluation, ethical reflection works with social and cultural constructs which are more fluid and need an ethical theory to be evaluated. Starting from the ways in which CT is approached in education, I propose the following operationalising of ethical reflection in education (see Table 1).

Table 1 CT and ethical reflection components

Target of learning goal	CT approach	Ethical reflection approach
Self-awareness (meta-cognition)	Awareness of one's own cognitive biases	Awareness of one's own moral inclinations
Domain-specific assumptions	Challenging the assumptions in a given knowledge domain	Challenging the normative assumptions of decision-making tools and ethical frameworks
Context sensitivity	Recognition of most common fallacies in a knowledge domain	Recognition of moral thinking biases based on moral psychology
Carefulness and conscientiousness	Careful examination of all available evidence, seeking evidence which may contradict it	Looking for hidden actors and indirect stakeholders, listening to the reasons of the situated actors

3. TEACHING ETHICAL REFLECTION IN THE ENGINEERING ETHICS CLASSROOM BASED ON CRITICAL THINKING COMPONENTS

Similar to teaching CT, ethics education for engineers relies heavily on case-based exercises [10]. In working with cases, students tend to "problem-solve" it, and look for the only correct answer. Meanwhile, the goal of becoming better moral thinkers lies not in coming to an acceptable moral solution, but in the way in which the student engages in the reflective process. Modelled by the CT learning goals, I will propose some steps that can be taken when working through an ethical case in the classroom. One classical case in engineering ethics education is the problem of the engineer witnessing that one's colleagues cut corners in their work, which may lead to increased risks for the beneficiaries of the design/ artefact. Should the engineer report to a superior, be complicit in the sloppy work, say nothing, or go to the press (whistleblowing)? Working through this exercise in the classroom by following the four learning goals of ethical reflection could proceed thus:

1. *Self-awareness*: before being given the case, students will be asked to take the ethical position questionnaire,[2] which classifies students into relativists and absolutists about moral knowledge. After students decided individually what the engineer in the case-based exercise should do, they are asked to compare their solution with their colleagues who had different results on the questionnaire. Later they are asked to reflect how much their previous moral outlook influences the kinds of solutions they find morally acceptable.
2. *Domain specific-assumptions*: All normative frameworks have an implicit view of human nature and the world. Students are asked to iteratively apply different ethical theories to the same case study - for example by using the ethical cycle method [16] in which they apply multiple ethical frameworks for the same problem, they compare the results, and arrive at their solution by reflective equilibrium. This method helps students understand that there is no one correct solution for the exercise and that the ethical frameworks have their limitations and should not be used as "calculating rulers".
3. *Context sensitivity*: Students learn the specific ways in which moral cognition can go wrong by studying the common biases in moral psychology (groupthink, conformity bias, action bias, diffusion of responsibility, etc.). After having come to a solution to the case at hand, they are asked to find biases in their own solutions as well as those of others'. After a few iterations of this exercise, the students' context sensitivity would increase.
4. *Carefulness:* Students are asked to role-play and take on multiple roles, with different personalities and interests, and reason from that specific angle. Initially, they are given the role of the engineer who notices the sloppy work of a colleague. But then, after coming to a solution, the student is asked to reason for the same case by switching the role and to imagine oneself in the shoes of that sloppy colleague, and then, as the client, the manager, and other stakeholder roles. If possible, students should be encouraged to discuss with actual stakeholders involved in situations similar to the case. By gathering different stakeholder perspectives, students will reflect more carefully before rushing to a conclusion of the right thing to do.

This paper proposed four approaches from CT education as an inspiration to teach ethical reflection, thus far a vague concept in education. Without claiming that CT overlaps fully with ethical reflection, their partial overlap in the critical attitude required from the students makes it worthwhile to attempt borrowing methods that work from CT and transplanting them into the process of ethical reflection.

[2] https://richmond.ca1.qualtrics.com/jfe/form/SV_dgSm3zr3XgSGRZX?Q_JFE=qdg

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THE POTENTIAL OF ONLINE LABORATORIES IN STEM EDUCATION; FIRST STEPS TOWARDS AN INTERNATIONAL COMMUNITY OF PRACTICE

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ABSTRACT

Access to practical laboratory exercises has always been a challenge in STEM education and is even more of a problem in online or distance learning programmes. In this paper, some training demands in STEM, related to experimentation and the operation of equipment, and the ways in which distance education can contribute to them are systematized. After a brief description of the different forms, some experiences that have been implemented in different parts of the world are compiled. It will also describe efforts that are underway to create an international community to share ideas, equipment and carry out collaborative research into the possibilities and impact of these efforts.

1 INTRODUCTION

Distance education has always had more significant challenges in engineering because of the need to meet learning outcomes in experimental methods and in the operation of physical equipment. This has, in the past been dealt with by compulsory residency requirements or in a limited number of cases by creating kits that can be posted out to students. The objective of this paper is to argue for the benefits of remote access to laboratory and other practical learning experiences (including simulations) and the need for creating an international community of practice dedicated to this topic. It will describe the scale of the challenge and the consequent benefits of building an international community of practice and how technology can help in both the creation of individual learning experiences and in building a community. It will list examples of existing networks in this domain and argue that a wider more inclusive network is required and describe the work completed to date in creating that community.

2 MOTIVATION

2.1 Challenges for remote and campus learning

It should be noted that access to laboratories is also an issue for residential students as well as remote learners, due to expense, safety and other issues. They may only having access to a limited range of equipment and for very limited periods of time [1] often resulting in graduating students who do not have the full complement of skills they need. Also, from a pedagogical point of view, students may not: 1) have the time required to investigate various scenarios of particular phenomenon to improve understanding and develop research skills, 2) be properly laboratory sessions and 3) feel comfortable enough working with certain systems due to safety hazards in some experiments.

2.2 Online laboratory access can help

It is clear, therefore, that facilitating online access to practical learning experiences can help improve the quality of learning of both distance and campus learners [2, 3, 7]. ‘Online laboratories’ is a term that comprehends many forms of experiences mediated by technologies. Certain types of online labs are: virtual laboratories (or simulations), remote, hybrid and digitized. Simulations have been used successfully to improve understanding of phenomena. Some research indicates that less time spent on physical equipment along with more time spent in simulators leads to both better understanding and recall [13]. Research on cognitive and social psychology applied to STEM education and learning has triggered a crucial shift from teacher to student-centred pedagogic approaches as from the mid 20th century today [14], [15]. Virtual laboratories that visually reproduce experiences may well improve learning outcomes even further, but these are much more expensive and time consuming to develop.

Many educators believe that for certain learning outcomes remote access to real physical equipment may be the best solution as they not only familiarise the student with the equipment that they may use in the workplace, they also replicate many of the errors and challenges in using real equipment that are not necessarily apparent in mathematical or visual simulations but are more expensive and difficult to set up than normal laboratories. Other perceived drawbacks of remote labs are the student to student interactions that occur within a lab setting [16].

Digitized Laboratories represent a compromise between Virtual and Remote. These applications use real data collected previously from a range of experiments and replicate the normal errors in experimental measurement. Some advantages when compared to remote ones include: 1) concurrent users, 2) minimal maintenance costs and 3) cosntant availability. Disadvantages include: 1) time required and difficulty in collecting the required data, 2) some experiments present just too many possible configurations and states to be able to get a complete and trustworthy enough data set. Hybrid also represents a compromise between Virtual and Remote. These labs combine the use of mathematical models and simulations to represent an equipment, system or process with real actuators and devices to perform control operations that, instead of being transmitted to real-world processes are applied to the simulated system. The main advantage of this approach is that this type of online lab is cheaper, but they inherit several disadvantages from virtual and remote labs.

2.3 The scale of the challenge

Whereas the creation of one online practical learning experience may be possible for a single professor or small team in a reasonable period, this is not feasible for a full course or multiple courses. For an institution, the challenge is several orders of magnitude greater.

2.4 International Community of Practice

In view of the scale of the challenge it is clear that there are significant benefits in sharing. For that reason, this paper is proposing the formation of an International Community of Practice. This approach consists in a collaborative activity [17] through different modes of sharing [18,19]. The use of ICT in education has led to the creation of online communities of practices, which may refer to very particular learning experiences by virtual encounters to foster global citizenship and an international orientation in education [20]. This community of practice is essentially about sharing knowledge (as opposed to creating knowledge). It should be noted that the core objective is not to necessarily to create online versions of lab experiences but the achievement of practical and experimental learning outcomes which are achieved in a campus laboratory experience. Members will be interested in any workable solutions that can allow their remote students achieve these outcomes.

The main objective of the community would be to collaboratively share and structure a database of solutions in a way that can easily be searched. These would include the following:

- Designs for remotely accessible experimental rigs
- Remotely accessible rigs that are available to other institutions.
- Freely and commercially available simulations, Virtual Labs and Digitized Labs.
- Designs for kits that can be assembled and posted to students.
- Commercially available kits and suppliers that assemble customised kits or provide technological solutions for developing and deploying online labs.
- Designs for home or work-based exercises based on widely available materials.
- Student-centered design strategies and best practices

2.5 Existing networks

A small number of such networks already exist, many concentrating on a subset of the objectives listed above or confined to specific regions or domains.

- European funded project Go-Lab (https://www.golabz.eu/): This site offers a collection of online labs (mostly virtual, an some remote) and try-out interactive inquiry apps.
- European funded project PILAR (http://pilar.ieec.uned.es:8282/aboutus) proposes a solution to the widespread use of VISIR [8] remote laboratory, as the mounting components on the relay switching matrix is limited due to the limited number of nodes and component boards. The project aims to interconnect all VISIR systems with each other in order to create a grid laboratory shared and accessed by all the participants, expanding and empowering existing systems to a new level of service and capacity. This allows expanding the application range: each university may install certain circuits on its own VISIR and utilize another type of circuits installed on a VISIR of other universities and vice versa.
- Spanish Network UNILabs (https://unilabs.dia.uned.es/): This network is formed by Spanish universities primarily and focuses on control systems online laboratories in the form of both virtual and remote ones. The main objective of the network is to share the online labs among the universities that are part of the network.
- Open University's OpenSTEM (http://stem.open.ac.uk/study/openstem-labs)
- India's Virtual Lab (http://www.vlab.co.in/): A country-level effort promoted by the government of India to provide virtual labs to universities and high schools in India.
- Thomas Bata University's ISES Remlab Net : 18 remote labs on different fields of Physics, freely accessible.(https://www.ises.info/index.php/en/laboratory)

- Open Source Physics (https://www.compadre.org/osp/): The OSP collection of the COMPADRE library provides curriculum resources, in the form of simulations, that engage students in physics, computation, and computer modeling.
- Colorado University's PhET (https://phet.colorado.edu/): Another free collection of interactive math and science simulations, similar to the OSP project. PhET simulations (158 are available at the moment) are based on extensive education research and their focus is to engage students through an intuitive, game-like environment where they learn through exploration and discovery.

Despite their many differences, all the above networks have something in common: they focus on sharing online lab end applications rather on promoting, discussing and sharing tools for developing your own labs for remote learners, good practices, experiences and so on. Many feel that there may be even more benefits to building a worldwide community of practice particularly for individuals who wish to share ideas, and resources with others in their own subject or sub-domain. Such networks benefit significantly from scale and as there are so many sub-domains this approach is more likely to be successful if it covers the largest population possible.

2.6 Building a sustainable community of practice

Many virtual communities of practice already exist and many of these have been able to operate on a totally voluntary basis with minimal costs incurred. The Internet essentially lowers the financial barriers to entry. At the time of writing, a LinkedIn group, "Labs for Remote Learners", has been formed with approximately 270 members (https://www.linkedin.com/groups/12072791/). Should this community prove to be useful to STEM educators, it will most likely need to move to a financial footing at some point. However, as online communities of practice can be very lean, it need not necessarily require paid membership. It may be that it can become financially sustainable through grants, running events and sponsorship.

3 SUMMARY AND ACKNOWLEDGMENTS

More flexible and cost-effective access to education is a worthwhile objective. While there has been significant progress in achieving the learning outcomes of normal classroom practices online, facilitating practical and experimental work has been more challenging. The range of topics where flexible solutions are required is such that no individual academic or institution can address this on their own. It is the authors' hope that by building an online Community of Practice we can make it easier for individuals and institutions to help both their remote and campus students to better achieve practical and experimental learning outcomes.

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ATTITUDE OF STUDENTS TOWARDS MODERN APPROACHES OF BLENDED AND FLIPPED LEARNING

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ABSTRACT

Being a very advanced learning format, blended learning involves both offline and online learning activities within the same discipline or course. Flipped learning is a model of blended learning when a passive format of lectures is delegated to independent work before a full-time meeting with the teaching staff. Thus, the phase of active learning is expanded and the effectiveness of full-time work in the audience increases, since offline work hours are redistributed into active learning formats. This study focuses on students' perception and attitude of blended and flipped learning as a university teaching format. The paper also discusses the issues of motivation of students with the aim of more extensive implementation of these formats in the educational programs of Russian universities.
Students of Tomsk State University of Control Systems and Radioelectronics (TUSUR), Tomsk, Russia, had to answer a series of questions on the formats of online learning and offer recommendations to overcome the limitations of these learning approaches. Overall, the study aims for analysis of students' attitudes while discussing the following questions: (1) What is the difference between blended and flipped learning approaches? Which approach is more effective? (2) How are blended learning formats useful for students? (3) How can students be encouraged and motivated to engage themselves in a flipped learning format? (4) How can students be motivated in choosing flipped courses, provided that these disciplines are not in the study plan?

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1 INTRODUCTION

1.1 Paper Summary

Flipped learning is seen as a model of blended learning when a passive format of lectures is delegated to independent work before a full-time meeting with the teacher staff. This is basically the difference between flipped and conventional offline learning approaches. The material is studied by students independently before the start of the lesson with the help of diverse ICT aides (video lectures, interactive elements, online presentations). All this results into a greater time resource during an offline class that could be aimed at hands-on tasks: solving problems, group interaction, team work. Thus, the phase of active learning is expanded and the effectiveness of full-time work in the audience increases, since offline work hours are redistributed into active learning formats. Flipped learning model assumes that the direct instruction is shifted from the group learning space to the individual learning space transforming the group learning space into a dynamic, interactive and creative environment [1]. This study presents the results of the joint work of the focus group of university students on the issue of discussing modern formats of blended and flipped learning. Also, the paper discusses the issues of motivation of students to be engaged in flipped learning courses with the aim of more extensive implementation of these formats in the educational programs of Russian universities.

1.2 Blended vs. Flipped learning

Blended learning usually implies the combination of offline and online educational approaches. This type of learning, by its essence, is not limited to technical issues or distance-learning students, but it represents an effective combination of educational content delivery modes as well as diversity of teaching models and learning styles [2]. A flipped classroom is a teaching methodology that makes part of the blended learning approach when a traditional class setting is inverted shifting lecture and some other study materials outside the class [3]. Implementation of flipped classrooms is documented as a beneficial instructional design with positive responses from students [4]. Despite this fact, there are some discrepancies in students' perception of flipped learning, learning outcomes compared with traditionally delivered classes, and the role of educators in facilitation of the learning process [5].

2 METHODOLOGY

2.1 Rationale for the study

A vast majority of offline courses at Tomsk State University of Control Systems and Radioelectronics are supplemented with online course modules on the Moodle platform, so students of the university are considered to have a high degree of awareness in terms of online education. Also, they are usually seen as being fully equipped with the knowledge and skills for blended learning. Therefore, educators envisage the situation with joining together offline and online educational activities as an efficient way to enhance leaning outcomes. As a rationale of this study we

assumed the necessity to investigate awareness and attitude of the students towards flipped classrooms, which make part of blended learning.

2.2 Design of the Study

The focus group of chosen 4 participants for the present study possess some experience in preparing educational materials for the flipped course “Innovation Systems and Technological Development”, which is being developed at TUSUR as a part of the CEPHEI - Industrial E-Learning project supported by the Erasmus + program. Also, the participants of the focus group have 2 years of experience of participation in blended learning courses at TUSUR on the Moodle platform. Students of TUSUR, Tomsk, Russia, had to answer a series of questions on the formats of online learning and offer recommendations to overcome the limitations of these learning approaches. Overall, the study aims for analysis of students’ attitudes while discussing the following questions:
(Q1) What is the difference between blended and flipped learning approaches? Which approach is more effective?
(Q2) How are blended learning formats useful for students?
(Q3) How can students be encouraged and motivated to engage themselves in a flipped learning format?
(Q4) How can students be motivated in choosing flipped courses, provided that these disciplines are not in the study plan?

3 RESULTS

3.1 (Q1) What is the difference between blended and flipped learning approaches? Which approach is more effective?

Despite the fact that the students of the focus group have sufficient experience in online learning, it turned out to be a difficult task for them to specify the characteristics and differences of these two educational online formats. Students generally highlighted the benefits of blended learning through opportunities to reduce study time through self-study, possibility to consult with teachers when needed, and help on behalf of educators in prioritization of study materials key points.

3.2 (Q2) How are blended learning formats useful for students?

Students noted that thanks to blended learning, the knowledge foundation is being developed on the necessary topics. Moreover, it becomes possible to independently distribute and re-distribute time for educational tasks. As a crucial point, it was mentioned that the blended learning format significantly contributes to enhance skills of independent work and self-study. Students emphasized importance of blended learning in acquiring skills of analysis and systematization as well as critical thinking and systemic thinking. Skills of time management are also being developed.

3.3 (Q3) How can students be encouraged and motivated to engage themselves in a flipped learning format?

Among the ways of motivation that can encourage students to take flipped learning courses are: (1) a system of automatic passes, which is subject to the strict study rules and deadlines if a course is delivered in the blended (flipped) learning format; (2) a rigorous disciplinary approach using the "stick and carrot" method; (3) a long-term strategic decision to foster discipline from childhood in favour of responsible behaviour and a change in mentality; (4) the introduction of a collective (group/team) responsibility regime in case of non-compliance with the rules of the game when working within the framework in the format of flipped learning.

3.4 (Q4) How can students be motivated in choosing flipped courses, provided that these disciplines are not in the study plan?

The proposals included: (1) spreading word of mouth, provided that the course in this format is already a successful educational product; (2) a creative and unusual approach to the presentation of the study materials that requires a creative approach from a course developer or a teacher (as triggers are seen the following: a breath-taking introductory lecture, an interesting life story, entertaining cases with discussions at the start of the course); (3) reputation of the teacher or course developer that already implies the existence of the previously acquired experience and reputation as a valuable asset.

4 SUMMARY AND ACKNOWLEDGMENTS

Overall, the current research results received from a small focus group will be used to develop a semi-structured survey to continue the study with the presented research questions for an enlarged audience of Tomsk university students to verify research outcomes.

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INTRODUCING AGILE CONTINUOUS EDUCATION (ACE): OPPORTUNITIES AND CHALLENGES

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ABSTRACT

The rapid pace of innovation is challenging industries to train professionals with updated skill-sets in a continuous and rapid manner. Current academic systems enable expertise acquisition primarily through graduate-level programs. While such programs are valuable, they can also be somewhat monolithic for full-time employees balancing personal, professional, and financial obligations.

MIT Open Learning is currently developing what we refer to as an agile continuous education (ACE) model, which will provide education in a flexible, cost- and time-efficient manner, by combining modalities: online (such as MITx micro-credentials), on-site (such as MIT Bootcamps), and at-work-site (through apprenticeships and professionally mentored project-work).

This more granular approach affords a degree of freedom to students in their professional lives by: (a) letting them try new content before pursuing full-time academic programs; (b) acquiring content and credentials in smaller bite-sized chunks; (c) allowing them to customize their path based on personal preferences and rapidly-evolving industry needs; (d) applying learned skills and knowledge in more rapid cycles; (e) enabling these benefits in a more cost-effective manner.

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This ACE model is promising but also challenging. First, designed programs must faithfully apply the science of learning. Second, these new building blocks must be standardized. Third, a new paradigm for unified transcripts is needed to accredit and record achievements. Finally, we are concerned utilitarian approaches to designing this system might lead us to neglect foundational aspects of education (i.e. humanities, field that must be preserved in any change). This paper introduces the ACE model and discusses unique advantages and challenges.

1 INTRODUCTION

1.1 Rethinking the Education Model

There is a constant interplay between innovation and education [1]. Technology innovation increases academic and workplace problem-solving but, in the process, changes the tools that professionals use. Business model innovation also transforms industries, merging some and disaggregating others. The combined dynamic redefines what activities are core [2] and influences what skills and job functions performed by professionals increase in importance, stay similarly relevant or become obsolete. Despite its complex and often varied effects, we need innovation. We face many challenges as a global society, and they will not be solved by conventional means [3].

So how do we promote innovation? It starts with recognizing that innovation is a people business and that to promote innovation, we need to update education [2]. Specifically, we need to find a mechanism for professionals to access rapidly advancing knowledge about the state of the art and then develop new skills. This is not an easy task, and remains a central challenge for education today.

Current academic systems enable expertise acquisition primarily through graduate-level programs. The spirit of the current system is to offer programs that are substantial enough to prepare learners for the needs of tomorrow. While this is valuable, this strategy is also risky in a rapidly-changing world. How can higher education institutions be sure they know what professionals might need tomorrow? Moreover, wouldn't it be better also to have professionals offering insights on what they need so that higher education institutions take that into consideration and respond accordingly, but also with research rigor, to best help them?

Traditional programs often have further limits including (a) program cost and time requirements, (b) the availability of certification only at the end of the program; and usually, for full-time graduate students, (c) the opportunity to apply the new knowledge and skills only after graduation [4,5]. So, the current design can be somewhat monolithic and thus exclude full-time employees balancing personal, professional, and financial obligations. Responsibly adapting to this dynamic creates a need for education that is both rapid and continuous. Importantly, this education needs to be highly practical but following a model based on rigorous educational research, and conveyed in a fluid, flexible, digestible way.

The engineering education community has already started to acknowledge and promote a shift from content-based to content-and-skills-based education [6]. While content delivery has been a common practice in higher education institutions, the

current paradigm needs to be updated to include development of such valuable professional skills as problem-discovery and problem-solving, ethical reasoning, team work, communication, creativity, and critical thinking. It is the command of these skills that allows the professional to bring to bear the value of content expertise.

1.2 Agile Education is a Current Need

MIT Open Learning (OL) aims to transform teaching and learning at MIT and around the globe through the use of digital technologies, in an open, collaborative and innovative way, guided by the latest evidence from the science of learning. MIT OL is currently developing what we refer to as a model of agile continuous education (ACE). The ACE model will provide education in a flexible, cost- and time-efficient manner, by combining a broader range of modalities: online (e.g leading to credentials), on-site (e.g. leading to MIT Bootcamps credentials), or at-work-site (through apprenticeships and professionally coached project-work). These modalities on their part consist of a meaningful range of sub-modalities (such as online synchronous and online asynchronous) that further expand our design space.

To fully realize this mission, MIT OL has already created a great number of online courses and programs [7,8] as well as supplemental digital resources, responding to the continuous demand from professionals to upgrade their skills and content knowledge. It has also spearheaded the use of digital credentials to certify content and skills acquisition [9]. Specifically, for over 7 years, MIT has offered more than 200 MITx online courses at the undergrad and graduate level; created 4 MicroMasters pathways (highly intense, graduate-level courses with credentials accepted by some MIT residential graduate programs upon admission and by more than 34 different universities from 21 countries); developed the xPRO courses and 5 program series (courses focusing on training professionals in state-of-the-art topics ranging from leadership and negotiation to machine learning and data science); created MIT Bootcamps (a blended program that combines online preparation with on-campus, intensive, week-long workshop for select learners to advance their knowledge); and, along with other leading universities, co-founded the Digital Credentials Consortium (DCC) to design an infrastructure for digital credentials of academic achievement. With all these resources at hand, MIT OL is now seeking to offer a new educational model to enhance the 21st century education.

2 THE ACE MODEL STRUCTURE

The ACE model offers every professional an opportunity but we expect that ACE would be a particularly effective solution for young professionals. This is because for young professionals the gap between increasingly-steep requirements of early-career jobs and concomitant preparation achieved through traditional education is high.

ACE learners would explore, follow, and ultimately craft for themselves, with guidance, a granular professional path that better suits their needs and interests. They would select from a range of courses and activities that are **online, on-site**, or **at-work**, or combine any of them together. To upgrade their knowledge and skills they would (a) take online courses available in the edX platform from the MITx and xPro portfolios; (b) participate in intense hands-on on-site and at-work MIT bootcamps; and (c) apply the new content and skills at-work, either through apprenticeship programs or by

participating in carefully structured and mentored activities designed to be directly implemented at the workplace. The online, on-site, and at-work activities are articulated; and this process is cyclical: learners can return to advance their knowledge and skills continuously. Figure 1 presents an example of how three different learners could follow three different paths, each one specifically tailored to their needs, and structured with support from mentors. Before completion of each one of the academic modules the students can choose whether they want to obtain a digital credential certifying the content and skills acquired at an additional price. These credentials are also accepted by other higher education institutions, a fact that further enhances flexibility in education.

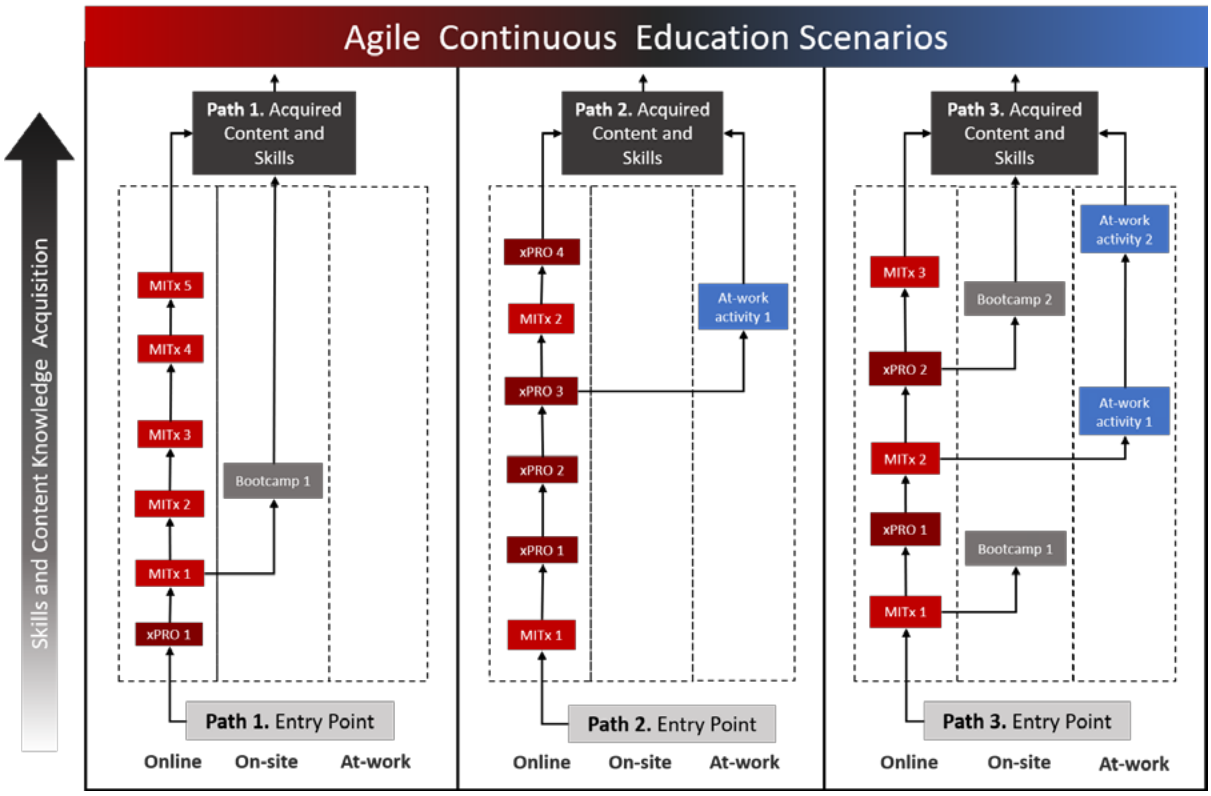

Fig. 1. Three different scenarios taken by different learners following the proposed ACE model

3 IMPORTANT CONSIDERATIONS

3.1 Opportunities and Challenges

The proposed ACE model presents promising opportunities. It offers a more granular approach and valuable degrees of freedom to professionals seeking to improve their skills and content knowledge by:

a) allowing them to try new content before pursuing a full-time academic program;
b) providing content and credentials in smaller size modules in shorter time periods;
c) allowing the students to customize their path based on personal preferences and the rapidly-evolving industry and society needs;
d) giving the students the opportunity to instantly apply the learned skills and knowledge at work;

e) and enabling all these benefits in a more cost-effective manner.

Now it is important to state that the development of the ACE model does not come without considerations and challenges, both in regards to the content and articulation of the different modules, the pedagogy selected for implementation, as well as the path logistics and course credentials.

With respect to the pedagogy selected to present the courses or bootcamps, MIT OL aims to develop and deliver new courses guided by the latest evidence from the science of learning, an effort currently underway [10].

About the content, although most of the existing online courses developed in MIT OL so far belong to the STEM and Business fields, both MIT and the global Engineering Education community acknowledges the need for the development of ways of thinking that are better rooted in the humanities [6, 11-12]. The development of ethical thinking, critical thinking, humanitarian thinking, as well as a better understanding of local and global contexts and cultures should be integrated with the technical, scientific, or entrepreneurial topics presented in every course.

Finally, it should be clearly noted that, despite the appealing benefits, this model is only suggested for people that already followed a formal undergraduate training. ACE, by no means, aims to replace traditional undergraduate education. Moreover, part of the implementation philosophy of ACE can be to support undergraduate education where this would be valuable and needed.

3.2 Future Considerations

Beyond the aforementioned challenges, we pose further questions for the entire higher engineering education community to consider at large when exploring an agile education model for the 21st century:

- How can the ACE model achieve efficient and scalable inclusion of coaching and mentorship in the selection of and progress toward career goals?
- How does the content reflect humanities and social sciences? And in what ways could ethical thinking be integrated with the STEM content?
- How can we as a global education community get ACE standardized? What should the new paradigm be for accreditation, unified transcripts, and record achievements?

Keeping these considerations in mind, the ACE model presents itself as an opportunity to improve graduate and workplace education. This model will make possible new relevant content combinations and, importantly, embed the delivery of that content in the context where it would be best received.
The ACE model should not be seen as a threat to traditional education. It is not and it is not meant to be. In the current environment we are all concerned about the current state and the future of this essential societal institution. We believe that ACE can promote a cycle of education and: the more professionals are able to access education instantly and effectively, the more they would bring knowledge to their community and work; the more they would create economic and social value, the more they would

meet the new frontiers of unsolved problems, thus creating the further and greater need for access to knowledge.

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A NEW BLENDED ASSESSMENT SYSTEM FOR A BASIC ELECTRONICS COURSE

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ABSTRACT

We must educate and prepare our engineering students for their future careers. They need life-long learning skills in order to keep in pace with the fast developing world, and this requires versatile and various skills. The students need to be able to work in different ways. They have to take care of schedules and they need to divide their working time in a proper manner between different tasks. In addition, complex problem solving skills are essential for future engineers. In order to achieve the required level in problem solving skills for future engineering tasks the students need strong understanding of the subject matter (theory) combined with firm hands-on working skills (practical work).

In this study, we developed and implemented a blended assessment system for a basic electronics course. With this system we wanted to familiarize the students with different ways of working and assessment in order to increase and diversify their learning skills. Furthermore, we wanted the students to clearly recognize the importance of even workload throughout the whole course. We collected written student feedback specifically concerning the assessment system in the course. In this study, we describe the blended assessment system in the basic electronics course and the results of the student feedback concerning it.

INTRODUCTION

1.1 Blended assessment

Blended assessment (continuous assessment, embedded assessment) can be defined as an assessment that occurs as graded assignments that are distributed

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throughout the course [1]. As a summative assessment, which measures students' achievements, this means that instead of one final exam the course grade is determined by various assignments distributed along the course [2]. It has been shown that continuous assessment can have several benefits for learning. It can motivate students to study and make them to adopt a more continuous working style [3]. With continuous assessment students can learn e.g. presenting, problem solving and handling equipment [1]. Continuous assessment thus enables teacher to design assignments so that they train important work life skills. Continuous assessment is also suited for large student groups as the assignments or some of the assignments can be carried out as online activities [1]. This supports the idea of blended learning, which on the other hand brings further benefits for learning, such as pedagogical richness and flexibility [4]. Continuous assessment, however, also has challenges. It requires more time from teachers, it may increase students' anxiety due to the feeling of being constantly assessed and it may offer possibilities of cheating [1]. Careful design of the various assignments and the overall workload are thus needed [5].

1.2 The blended course assessment system

A basic electronics course in Tampere University has been using a new blended assessment system (BAS) for a couple of years. The course is implemented in the first year's second study period (duration 7 weeks). In addition to the extremely important theoretical subject matter knowledge the students need generic skills, e. g. various working and studying skills, scheduling and in the electrical engineering also strong measurement, simulation and prototyping skills. We kept all these in mind when the new BAS was developed. With this system we wanted to boost students' learning and provide them with necessary theoretical, practical and generic skills.

The BAS was designed to be continuous. This way the students learn to work continuously, and they can concentrate on the issues in smaller pieces. In addition, we wanted to combine continuous training of practical skills with the problem solving skills. These skills also have a strong effect on the final course grade.

The course contains four main subject areas. An exam question (EQ) is after every main subject area. The EQs are comparable to the course's previous traditional end exam questions. This way we could efficiently increase students' continuous working along the course and familiarize them with important scheduling skills. The theoretical knowledge is tested in an electronic exam (EE) at the end of the course. Each student can book a suitable time for the EE. With the EE we wanted to familiarize the students with doing on-line exams, and we also wanted to do the BAS more flexible concerning time and place. In addition, there are weekly exercises (EX) during the course. The EX contain calculations, simulations and circuit prototyping with measurements. The students have BYODs (Bring Your Own Device), with which they can do circuit prototyping and measurements wherever and whenever they like.

The compulsory parts in the course assessment as well as the minimum requirements and the maximum points for each compulsory assessment part are gathered in Table 1. If a student does not exceed every minimum requirement, the student does not pass the course. However, the student has usually 3 possibilities to redo all the compulsory parts and to increase one's points. The minimum requirements of each assessment part ensure that all the students passing this course will have at least the minimum required level of knowledge and skills in each course area.

Table 1. The compulsory parts in the course assessment.

COMPULSORY PART IN COURSE ASSESSMENT	MINIMUM REQUIREMENT
EQs (4 altogether, 6 point max each)	2 points in every question
EE (at the end of the course, 14 points max)	4 points
EX (six times along the course, 2 exercise points available in each weekly exercise set, total max 12 exercise points)	6 exercise points

A student gathers course points (CP) of each compulsory part. The CPs from different compulsory assessment parts are shown in Table 2. At the end, all the student's CPs are added, and the course grade is determined based on them. Table 3 describes how the course grade is formed based on the CPs. The students see their points in Moodle along the course. This way they can do self-assessment during the course, plan their working properly and aim to a certain course grade. Furthermore, the students' self-regulation skills develop when they plan and schedule their own doing in this course.

Table 2. The CPs from each compulsory assessment part after the minimum requirements have been passed.

EX POINTS	CP / EX	EQ POINTS	CP / EQ	EE POINTS	CP / EE
6	0	8-9	0	4	0
7	1	10-11	1	5-6	1
8	2	12-14	2	7-8	2
9	3	15-17	3	9-10	3
10	4	18-20	4	11-12	4
11	5	21-22	5		
12	6	23-24	6		

Table 3. Course grade based on the CPs.

CP	COURSE GRADE (scale 1 to 5)
0-2	1
3-6	2
7-10	3
11-13	4
14-16	5

2 METHODOLOGY AND RESULTS

Every student taking the compulsory EE had to give feedback from the BAS. The students wrote freely the original feedback. The total amount of students was 128. The written feedback was analysed using simple thematic qualitative text analysis. The original feedback was categorized to six main categories (C). The categories were formulated inductively based on the frequently risen issues in the feedback. One original written feedback of one student can be included into many of the categories, if it contained many of these issues.

The results of the feedback analysis are in Table 4. The results clearly indicate that overall the BAS was good (C1 to C5). All the other assessment parts got clearly positive feedback from the students except the EE (C5). The opinions of the EE were divided quite equally to those who liked it and to those who thought it was unnecessary. The course includes a large amount of subject matter and has quite a lot to do. This is clearly seen in the results in Table 4 (C6). The students especially liked that the assessment was divided into many parts along the course (C2). In addition, some students did notice the importance of the minimum requirements in ensuring them at least the minimum level of knowledge at each important course area (C3). The importance of practical doing is noticed by the students (C4). In Table 5 there are some freely translated answers from the student feedback.

Table 4. Categorized written feedback.

CATEGORY	YES	NO
1. The assessment system was good.	49	1
2. Good that the assessment was distributed to many parts / was continuous.	77	3
3. Good that this system ensures that all have at least the minimum level of knowledge in each course area after this course.	10	8
4. Good that I could have an effect to my grade by collecting CPs from exercises. / Good that practical doing has an effect on the course grade.	34	4
5. The electronic exam was good.	11	10
6. The workload in the course/exercises was too big.	26	0

Table 5. Some freely translated quotations from the written feedback.

"I hope the coming courses have an assessment system something like this. My learning is much better this way, when I don't have to study the whole course content at one time, and I also think that I have a better chance to a good grade this way."
"Good that the exercises were in a significant role in the course assessment. It motivated me to do all the exercises."
"The assessment system is motivating. You can see your own CP accumulation along the course and you can adjust your doing according to the aimed course grade."
"One disadvantage is that multiple different parts in assessment increases significantly the student's performance stress."

3 SUMMARY

In this study we introduced a new BAS for a basic electronics course. We collected freely written feedback of the BAS from all the students passing the course. The results show that the BAS is working as we have planned: the students' workload is distributed more evenly along the course, the students learn, and like to learn, practical skills, and the students' learning in general is increased. In the feedback there were also opinions against this BAS, but they were in clear minority. Furthermore, we found issues for future development, e. g. how to reduce the workload so that the course still includes all the necessary skills and knowledge. The role of the EE must also be taken into consideration. As a conclusion we think this BAS is good and BASs should be taken into use also in other courses.

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BEFORE RESPONSIBLE INNOVATION: TEACHING ANTICIPATION AS A COMPETENCY FOR ENGINEERS

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ABSTRACT

This paper focuses on engineering ethics education utilizing Responsible Innovation (RI). As a forward-looking approach aiming to embed ethics within innovation practices, RI strives to align technology development with societal values. However, when teaching the concepts and methods of RI, we face two intertwined challenges. First, RI presupposes we can estimate the consequences of an innovation or design intervention, while evidence shows it is nearly impossible to fully predict the consequences of new technologies. RI acknowledges this by replacing an ambition to *predict* with a call to *anticipate* innovation-consequences. However, without a robust account of anticipation this merely kicks the can down the road. Second, RI seems to suggest that we know what is meant by a specific value (e.g., privacy, sustainability) and its relation to a specific technology. While such knowledge is key to an anticipatory perspective, values are often treated superficially and a-historically in RI literature. To address these challenges, we argue that RI-focused education – and engineering ethics generally – should be fostering *historically informed anticipation* as a core competency. To do so, we will define and characterize a set of interrelated virtues essential for engaging in historically informed anticipation: *moral sensitivity* (an ability to identify values at stake), *epistemic humility* (an awareness of the limits of one's understanding), and *moral imagination* (an ability to envision new perspectives and solutions). We suggest this can be cultivated via a novel teaching method that involves

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an in-depth historically informed normative analysis of a value-technology dynamic (called a *value-genealogy of technology*).

1 ENGINEERING ETHICS AS RESPONSIBLE INNOVATION

Over the past decade, the concept of Responsible Innovation (RI) has emerged as a guiding framework for technological innovation in the European context. At the most basic level, RI "is the on-going process of aligning research and innovation to the values, needs and expectations of society" [1]. Rejecting the position that technologies are value-neutral, RI maintains that moral values can be embedded in technologies, and that moral deliberation should be a fundamental element at all levels of technological research, development, and governance. RI can, as a concept, be understood via procedural (process-focused) and substantive (product-focused) dimensions [2]. As a procedural tool, RI explicates a process of innovation that meets identified societal norms (e.g., transparency, accountability, public participation), or that adheres to ethical principles such as non-maleficence and beneficence [3,4]. As a substantive notion, RI focuses on the outcomes of innovation, ensuring said processes result in artefacts or systems that positively foster identified moral values (e.g., safety, sustainability, privacy) [5].

While there are a variety of methodologies that fall under the umbrella of RI, two key unifying features can be highlighted. First, as an ethical approach to innovation, it is explicitly forward-looking. Rather than focusing on retrospective questions of responsibility and blame – a common approach to teaching engineering ethics – it asks how to develop technologies with, and for, society. Second, moral values are situated as fundamental considerations for engineering, design, and associated policy-making. Thus, the adherence to, or incorporation of, identified relevant values is situated as a "supra-functional" design requirement [6].

2 TEACHING RESPONSIBLE INNOVATION: TWO PROBLEMS

Given the constructive orientation of RI, the multiplicity of frameworks that have emerged to operationalize RI in different contexts, and the recognition of RI by governments, companies, and funding agencies, it comes as no surprise that it has also been also been incorporated into education. The concepts and tools of RI have become a fundamental component of engineering ethics training in various institutions, and ethics of technology courses more generally. However when teaching RI, and asking students to utilize different approaches as a research method, we typically rely on two intertwined (epistemic) assumptions:

- That we have a good sense of what the consequences of an intervention or innovation will be; and,
- That we know the meaning of a specific value in a specific context

Put otherwise, an assignment that asks students to "design X for value Y" implies we know both what the effects of (potential) innovations to X are, and have a clear and stable definition of Y. However, these assumptions should *not* be blindly accepted, especially when dealing with radical or disruptive technologies, which by definition

have the potential to transform, in unforeseen ways, the values we take for granted. Accepting that these assumptions should be addressed, we can therefore identify two interrelated challenges for teaching RI:

The Positivist Problem

The first problem calls into question the predictability of innovations and inventions, and the assumed linear relation between the design and use contexts of a technology. Based on theoretical and historical evidence, it has been argued that designer's intentions do not necessarily correspond with users practices. Rather, there is no essential or stable interpretation of a technology, but different uses that can emerge in different contexts [7,8]. Acknowledging the limits of foresight, RI literature rejects prediction as a goal, instead endorsing the importance of *anticipation*. Broadly put, anticipation is understood as an exploratory stance prompting "what if" questions, towards considerations of what is known, what is likely, and what is possible [3]. However, this opens up important pedagogical questions: what does *good* anticipation look like? How do we avoid excessively optimistic or pessimistic forms of anticipation? And, what activities give students the opportunity to develop this competency?

The Empty Signifier Problem

The second problem concerns the knowledge required to cultivate anticipation as a competency within engineering ethics education. Specifically, the goal of aligning innovation with societal values requires a nuanced understanding of what we *mean* by said values. However, this is not always clear. Values such as privacy or sustainability are so commonplace that we rarely question their origins, specificities, or legitimacy. Further, their (unquestioned) connotations can be co-opted to defend or reject a technology out-of-hand. This can result in superficial, ahistorical, and acontextual definitions – both in how such values are taught, as well as how students operationalize values in their assignments. While recent scholarship has drawn attention to this issue and proposed new mechanisms for addressing these deficiencies at a theoretical level, there is still the question of how to translate this rich (and evolving) debate into concrete teaching exercises. How can we structure exercises and assignments so that students move beyond a superficial identification of common values, towards acquiring a nuanced understanding of their import and meaning? How do we foster critical and reflective research into key values (*why does it matter, for whom, and how has it come to matter so much to us*)? And, how can students develop a sensitivity to the co-opting of values in arguments for or against a certain technology?

3 TEACHING RESPONSIBLE INNOVATION: FOSTERING 'HISTORICALLY INFORMED ANTICIPATION' AS A COMPETENCY FOR ENGINEERS

The *positivist* and *empty signifier* problems pose important epistemic challenges to the teaching (and practice) of RI, forcing us to question the limits of our knowledge. Yet, they need not be seen *only* as problems. Our proposal is that the above two

challenges can be re-framed as an opportunity to develop and refine RI teaching within engineering ethics, so that it confronts these issues head-on. This can be addressed, we propose, by focusing on a pre-condition for the successful application of RI theory. Anticipation can be situated as a procedural tool, and a benchmark for product development and associated policies. However, we can also position anticipation as a competency that should be explicitly fostered in the training of future engineers and designers, towards the goal of developing the knowledge and traits required for RI. Understood in this sense, we focus on anticipation as historically informed and as requiring the cultivation of a set of interrelated intellectual virtues – outlined below. Importantly, this competency is not bound by discrete knowledge and finite skills. Rather, it is about fostering a critical awareness of context and an attunement to the moral issues at stake therein. Thus, the virtues sketched below are about *how* to do RI, not *what* to do.

Moral sensitivity

We understand moral sensitivity as an overarching and fundamental requirement – for RI, as well as social and professional responsibility generally – that constitutes an attunement to *why* and *for whom* certain aspects of a situation or choice are morally relevant. As a facet of historically informed anticipation, it requires an ability to not just identify obvious values at stake in the design and introduction of a given technology, but also a sensitivity to a) the meaning of those values; b) the possibility of implicit biases obscuring the meaning of relevant values and the voices of relevant stakeholders; c) the interplay between identified values and the innovations that may affect the relevance we attach to them; and d) the presence of other (less obvious) values that may be at play too. Thus, moral sensitivity requires an attentiveness to the contextual meaning of values (e.g., the history of a certain value conflict).

Epistemic humility

Abandoning prediction in favour of anticipation requires that we also strive to engender a prudential outlook regarding possible futures. The social, environmental, and economic ramifications of emerging technologies are becoming increasingly complex and far-reaching. RI therefore requires a recognition of the limits of our knowledge about a technology, including the values it presumably instantiates and how innovations might affect different stakeholders, towards coping with the unforeseen consequences of failures *and* successes. The cultivation of a reasoned and critical approach can provide a middle-way between overly optimistic or pessimistic perspectives on new innovations [9].

Moral imagination

An anticipatory approach to technology development requires an ability to creatively explore the relationship between moral values and technologies, and to envision novel solutions to an identified (moral) problem. This should still be grounded in moral sensitivity and epistemic humility – in an attunement to ethical issues and some tempering of uncritical techno-optimism. Yet, a hopeful approach to problem

solving is essential for RI [9]. Coursework should therefore foster an open and exploratory outlook. This can be rooted in an acknowledgement of professional responsibility, while giving space to explore what sort of future we want, and why.

We believe that developing courses and exercises that explicitly aim to cultivate this set of intellectual virtues will inculcate the competency of *historically informed anticipation*. It will foster an appreciation of the limits of foresight, a critical perspective on the potential consequences of innovations and inventions, and a robust sense of values as socially, historically, and contextually contoured.

3.1 Historically informed anticipation in practice

Towards this goal, we propose a novel teaching methodology for engineering ethics, termed a *value-genealogy of technology*, focused explicitly on developing the competency of historically informed anticipation (Table 1). It is an open and explorative exercise, during which students will engage with a specific value-technology relation over the entire course – analysing how a value has shaped a technology and associated societal perceptions and policies, and vice versa. After an introduction to the main tenets of RI via readings and lectures, student groups will spend several weeks undertaking discussions and formative assignments related to their case. The exercises are intended to allow for an exploration of the historical relationship between the technology and the value, an analysis of meta-narratives shaping policies and public perceptions, and a critique of contemporary discourse.

Table 1. Overview of value-genealogy of technology assignment

Exercise	Objective	Output	Target Virtue
Writing 1: reflection	Reflection on initial impressions of the technology and value(s) to be explored	Short writing assignment	Moral sensitivity
Starter-kit analysis	Gain foundational knowledge via project description and initial resources provided by instructor	Identification of key values and (potential) conflicts	Moral sensitivity
Creating a genealogy	Critical analysis of historical texts, contemporary texts, and media	Mapping exercises of technology-value relations, conflicts, and predictions (past and present)	Moral sensitivity Epistemic humility
Presentation: (un)informed anticipation	Present results of genealogy via selecting two extreme perspectives (utopian and dystopian), and critically reflecting on the assumptions, biases, and context of those perspectives	Class presentation	Epistemic humility Moral imagination
Writing 2: informed anticipation	Analysis of initial impression, genealogy, and presentation; positing a future-oriented approach to case in line with RI	Essay	Epistemic humility Moral imagination

To help clarify and concretize this anticipatory exercise, the below box offers an overview of one value-technology case study that can be used in the exercise: the relationship between public order and (smart) lighting, resulting in a value conflict between safety, privacy, and surveillance. This text will constitute the introduction to the students' "starter kit," which will include readings on the social history of nighttime lighting, the ethics of smart cities, literature from companies advocating for smart lighting, and selected newspaper articles.

The Streetlights are Watching You: Values and Smart Lighting

Emerging "smart city" trends are spurring a new generation of streetlights, with lampposts being fitted with sensors, cameras, and a host of other novel technologies aimed at monitoring and data collection. While these innovations may offer improvements to efficiency and safety, they raise concerns about privacy, surveillance, and power dynamics. More fundamentally, such smart systems seemingly extend the technical functions of streetlights. No longer simply providing illumination, they actively monitor their environment and those who inhabit it, creating a vast network of nodes throughout our public spaces. Combined, the novel functions and capabilities of smart streetlights arguably create a new terrain of moral concerns. From such a vantage point, this technology acts as a socially disruptive force, profoundly altering the public spaces of cities and those who inhabit it. This has created a divide between the companies and cities championing the benefits of smart systems (the Utopians), and those who critique such technologies as socially and politically unjust (the Dystopians). What would a historically informed anticipatory intervention into this debate look like?

The history of nighttime lighting offers a nuanced perspective. Without denigrating contemporary concerns, we can find evidence that these seemingly novel issues represent a continuity with the values fundamental to the very notion of public lighting. Debates over social order at night – and the resultant tension between safety, privacy, and surveillance – have been a recurring theme for centuries. Streetlights have long been utilized as a form of policing and perceived as a symbol of authority, creating ongoing tensions between control and liberation in urban nightscapes. While offering significant improvements in accuracy, smart streetlights arguably embody a continuity of values – and value tensions – that can be traced back to the origins of public lighting in the 17th-18th centuries.

It seems that contemporary innovations represent new means of realizing these long-held goals, just as resistance to them offers fresh versions of protest and critique. But, do the possibilities of smart lighting technologies warrant a shifted perspective? Are these values (and value tensions) static, or do new innovations force us to re-think the meaning of notions like "surveillance in the public sphere"? How have perceptions of these values evolved with new lighting technologies, as well as social changes? Which stakeholders have a voice in (past and present) narratives about the technology? And, how are groups on both sides of this argument co-opting long-held ideas and associations (e.g., "lighting equals safety") to support their goals?

4 CONCLUSION

This act of developing a historically informed anticipation regarding a value-technology dynamic will – we propose – help students understand the context-specific meaning of a value, in turn allowing for a nuanced perspective on the potential social and environmental impacts of future innovations. While we will ask students to take a critical stance, as well as propose a constructive path forward, we are not asking for a final or definite "answer" to the question "will innovation X count

as an instance of RI?" Rather, we hope for a critical and reflective exploration of the mutual co-shaping of the value(s) and technology. We believe such an assignment will leave students – as engineers in training – better prepared to appreciate both the complexity of value-technology relations, and assist in habituating the virtues of moral sensitivity, (epistemic) humility, and moral imagination.

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A NEW APPROACH FOR TEACHING MATERIAL SCIENCES AT THE AUTOMOTIVE ENGINEERING PROGRAMME OF FONTYS UNIVERSITY OF APPLIED SCIENCES

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Conference Key Areas: *Engineering curriculum design, Future engineering skills*
Keywords: *automotive, materials sciences, course design, constructive alignment, inquiry learning*

ABSTRACT

The use of polymers for modern vehicle components brings about significant advantages for the appearance, comfort and safety of new cars. Understanding and knowledge of these concepts are important for versatile future automotive engineers. Previous evaluations showed that the more classic lectures setting was less motivating and engaging, and the content thought to lack relevance for this programme. The focus in this research is on the evaluation of the new design of the Material Sciences course.

1 INTRODUCTION

1.1 Importance of material science in Automotive Engineering curriculum

A wide variety of polymer materials are used to make vehicle components. The use of polymers brings about significant advantages for the appearance, comfort and safety of new cars. The manufacturing methods required to produce those materials vary greatly. In view of environmental issues, recycling becomes more relevant nowadays. Understanding and knowledge of these concepts are important for well-rounded future automotive engineers.
Previous evaluations of the Material Sciences course showed that the more classic lectures setting was experienced as less motivating and engaging by the students. Also, the content was deemed less relevant for the study of Automotive Engineering. At this moment, the learning output is therefore broad and shallow, and not specific enough for the challenges of an automotive engineer.

1.2 Research question

The question was raised as to whether or not a new format of the Material Sciences course could work better. After the first implementation, the focus here is on the evaluation of the new design of the Material Sciences course: Are the learning goals

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achieved with this new design, such that the students get more specific knowledge for an automotive engineer?

2 METHODOLOGY

2.1 New design according to the principles of the constructive alignment

According to the principles of the constructive alignment [1], how students study is driven by examination. Students focus on achieving the learning objectives if you set the examination up in such a manner that it measures the achievement of the learning objectives. The design of a course begins with determining the learning objectives, then the examination, followed by what the learning activities must involve in order to reach the desired learning objectives. Finally, the teaching materials and the teaching activities are designed. These principles are followed in redesigning the Material Sciences course.
The specific components of the Material Sciences course, according to the systematics of the constructive alignment, are:
Learning objectives: The students will (learn to) research one specific topic in the field of polymers used in the automotive industry. They can choose between car paint, car wraps, brake pads, helmets, Marlon/Lexan window glass, airbags, spoilers, isolation materials, head-and-neck-support, race overalls, and upholstery. For these materials, the students will determine their specific chemical composition, together with the physical and chemical properties. The students will explain related manufacturing and recycling techniques, how these materials are tested, and will present the most recent innovations trends. In a final report, the students will document all these aspects. During a poster market, the students will present their own work and will collect information from other students about other materials and applications in automotive engineering.
Assessment: A formative assignment, shortly after the start of the course, gives a quick feedback on the expected quality. The students will be able to immediately adjust their activities. For the summative assignment, there are two final products for this course, a report and a poster. The report contains a complete review of the polymers from their own topic, with all the subsequent perspectives. The poster supports free discussion with peers and faculty members during a poster market. The poster session is also meant as an important opportunity for the students to acquire information about the applications of polymers in other topics rather than their own. Both products, the report and the poster, are summatively assigned with rubrics [2] that closely follow the learning objectives.
Learning activities: The students work in small groups of 2-3 students, both face-to-face and digital. The students are helped with relevant workshops and with tailored support from a tutor. The students (learn to) look for and analyse relevant scientific information that they find in databases with scientific literature. Each group of students writes a report and makes a poster that presents the results.
Teaching materials: The students can use books and online databases, but can also consult their teachers.

Teaching activities: The teaching approach is based on inquiry learning [3], when students are presented with topics to be analysed and questions to be answered. Different teachers support the students during specific workshops with their own expertise (chemistry, material sciences, automotive, etc.) during the whole project. The students are instructed how to look for, to analyse and to judge relevant scientific information. The students are taught how to write a report, how to make a poster and how to present the results. This support can also be a drop-in tutoring hour.

2.2 Evaluation of the new design

The research focuses on the link between the learning goals and the actual knowledge of the students: not only were the final products quantitatively evaluated with rubrics, but also a qualitative research took place; teachers involved in the project and different students were extensively interviewed by the author. Their feedback will be used to adjust the learning activities in order to improve the match between the learning goals and the students' learning output.

3 RESULTS

3.1 Quantitative evaluation

The quantitative evaluation was done with rubrics [2]. The rubrics were formulated according to the learning goals and tested the achieved level. Each topic (polymer chemistry, manufacturing, testing, recycling, and present day innovations) and each final product (the quality of the report and the poster) were rated on a scale from 0 to 3. Zero points stated a non-existing item and three points stated an outstanding result. From the maximum of 21 points, each student had to achieve a minimum of 15 points. The students got two chances to complete the assignment. In the first round, a total of 29% of the students passed the evaluation (35 out of 122). The teachers gave feedback and the student subsequently got a second chance to improve. In the second round, a total of 68% (58 out of 85) of the students passed the evaluation. The quantitative evaluation says that 76% of the students achieved the learning goals.

3.2 Qualitative evaluation

The course was subsequently qualitatively evaluated by a series of extensive interviews with eleven students and three teachers. The majority of students found the new setting very attractive, more motivating and engaging than a classic lecture setting. The teachers share these opinions.
A question was if the students, at the end of the course, were still aware of the learning objectives and their achievements. The interviewed students stated that, from their own perspective, they had achieved the learning goals. There are though three noteworthy points:
Firstly, the students are not really aware of the learning objectives, but they all still report an achievement. That may bring the self-reflection in doubt. Secondly, they report that they split their own topic between the group members. Subsequently, only some of them fully reflected on all parts of their group's topic; the majority of them

only have knowledge of their own part. Thirdly, the poster session was meant for the students as the ideal moment to get knowledge on the applications of polymers in all the other topics. A poster session was for the majority of the students a new form of sharing and gathering knowledge. Therefore, they focused mainly on presenting their own work, but were not actively involved in gathering knowledge over other topics. The interviewed teachers notice two crucial aspects about the new design. Firstly, compared to the previous setting, the students now acquire more knowledge on their own topic, but they miss the overview of all topics. Secondly, the students are not able to place the information in a knowledge network, they see it as a stand-alone summation of facts. What the teachers miss are not only the cross-links between different parts of the same topic, but also the mutual links between different topics.

4 CONCLUSIONS AND RECOMMENDATIONS

Previous evaluations of the Material Sciences course showed that the more classic lectures setting was less motivating and engaging, with a content deemed as less relevant for the study of Automotive Engineering. The question was raised as to whether or not a new design, following the principles of the constructive alignment, would work better. The evaluation of the new design was presented here.
On the one hand, the students think that they achieved the learning goals. On the other hand, the teachers do not give a positive answer for everybody when answering the research question “Are the learning goals achieved with this new design, such that the students get more specific knowledge for an automotive engineer?”.
The first recommendation is for the teachers to realise an even stronger link between the learning objectives, the examination, and the learning activities, according to the principles of the constructive alignment. The second recommendation is that the goal of the poster market must be formulated even more explicitly and, subsequently, the market must be built accordingly. The poster session has a very important role: the students acquire information about other topics other than their own from the other students. In the results reported here, this is not yet the case.

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WHAT ARE GOOD TEAMWORK SKILLS AND HOW DO STUDENTS LEARN THEM?

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ABSTRACT

As modern STEM programmes move to focus on a more skills based curriculum, a different approach to conceptualising learning is required. Learning skills is a very different process to learning a list of technical information. In the same way that becoming fluent in a language requires more than learning a list of vocabulary.

Curricula are addressing this by moving away from solely using knowledge transfer methods and including multiple experiential learning experiences. These experiential learning experiences allow students to recontextualise existing knowledge, add experience or tacit knowledge to their learning and practise professional skills such as problem solving and communication skills repeatedly. [1] [2]

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For teamwork skills in particular, how student learn skills in this context is somewhat like a black box. [3] We hope that by opening the box lid, with the introduction of student self-reflection, we have increased the effectiveness of experiential learning experiences. Here we start to analyse these self-reflections to better understand the student team process in order to better support students in their learning.
This paper focuses on the teamwork skills section of our pilot study. We asked Chemical Engineering students to reflect on their teamwork experiences. We present some initial findings on student's ideas on teamwork skills and what they have learnt in their teamwork projects. Our findings show that students have a relatively broad view of what teamwork skills are and readily engage in the reflective practise needed to improve those skills.

1 INTRODUCTION

1.1 Adapting Engineering Education to a New Job Market

New engineering graduates are entering an employment market that is increasingly flexible and because of that, skills focused. Regularly published top ten lists of what skills employers are looking for consist almost exclusively of professional or soft skills rather than technical knowledge [4]. The question of how engineering curricula evolve to meet this challenge and prepare graduates for this new market has been discussed at length. Many leading institutions in engineering education have developed and implemented ambitious new curricula and incorporated new teaching methods [5].

One aspect of this is the move to a skills focused approach. Students are provided with multiple opportunities to acquire and practise the skills that regularly crop up in those top ten lists. Students work on group projects to learn teamwork, leadership and delegation. They present to each other improving their technical and non-technical communication skills as well as providing feedback to others. We ask them to produce design proposals and prototypes, on paper and in 3D, to get them familiar with the design process and improve their problem solving and practical skills.

1.2 Why do Skills Need to be Taught Experientially?

For many the need to teach a skill through repeated facilitated practice rather than the traditional knowledge transfer methods seems obvious. To learn a skill, you must practise a skill multiple times to properly understand it. Two concepts can help to us to understand why, recontextualisation of knowledge as discussed by Guile [1] and tacit knowledge, a catch all term used by many but for the purposes of this paper as articulated by Collins [2].

Guile's recontextualisation theory states that knowledge is not learnt once and never changed [1]. A piece of knowledge is not only the information contained in it but also every context that someone has used it in and the connections to other pieces of knowledge. The information contained in an organic chemistry textbook means one thing to a chemist and something different to a pharmacist because they bring the

context in which they use the knowledge to its understanding. Thus every time we use a skill we are recasting it in the context in which we are using it. Hence why we need to repeatedly use a skill to fully understand it.

Tacit knowledge as articulated by Collins was proposed to reconcile the fact that not all information on a scientific method could be included in a written account [2]. There is information that can't be expressed in a written account, for example local knowledge or information that is deemed inconsequential. In applying this idea to skills, becoming proficient at a skill requires a combination of theoretical knowledge and experience because learning a skill is more than learning a list of information.

A key aspect of improving our teaching practise is to understand how students are learning skills, to 'lift the lid' on student learning and use that information to inform and improve our practise [3]. The aim of our longitudinal study is to provide some insight into how student's learning progresses over time. The first step is to understand what students think teamwork skills are. We have used data from students' self-reflections on teamwork which they completed as part of their assessment for a team project. The self-reflections, the peer feedback they are in part based on, have been incorporated into teamwork assessment to walk students through the experiential learning cycle [7]. Previous work has used self-reflection to look at students' perceptions of how their skills have developed [8]. In depth discussion of the use of reflection can be found the literature and isn't the focus of this paper. Here we present some initial findings on students' conception of teamwork skills and what they learnt during teamwork.

2 METHODOLOGY

2.1 Project Work

First year Chemical Engineering undergraduate students are placed in groups of 5 or 6 and asked to work on a project over the course of a week, called a scenario [6]. Over the week, each team has various deliverables that they need to complete. As part of the assessment of the project, students are asked to complete a structured teamwork reflection individually. These are marked as pass/fail based on whether students complete the reflection. A sample of these reflections form the data set for this paper.

2.2 Data Analysis

Ninety-four students completed the reflection online in our online learning space and that data was extracted and anonymised before analysis. We used a thematic analysis of the data. The two questions we have analysed are *What Are Your Main Strengths?* and *What Did You Learn?*. To provide a structure for coding for the first question, coding was based around a list of teamwork skills from an undergraduate teamwork study guide [9] The. list contains a one or two sentence definitions of teamwork skills which was then converted into the one or two word phrases seen in table 1. Responses were categorised based on the skill definitions. As the coding for

the first questions did not fit the responses to the second question, coding was drawn from the data set.

3 RESULTS

3.1 What are Good Teamwork Skills?

Levin, in his study guide for undergraduate students on teamwork, when talking about the somewhat abstract idea of teamwork skills, provides two lists of skills, intellectual and emotional [9]. For him, the primary difference between intellectual and emotional skills being whether or not they can be taught in a classroom; the former can while the latter one can only learn through experience. Given the concepts of recontextualisation and tacit knowledge outlined previously, this difference seems very artificial but the list of skills does provide a starting point for analysing students' thinking on teamwork skills.

Below, in Table 1, are the results from coding the students' reflections on the question *What are your Main Strengths?* One important aspect to note is that whilst we have used Levin's teamwork skills as a basis for evaluating the student reflections, what is clear is that students' definitions of skills vary, with one of the most common being leadership*, "I believe that my main strength is leading a group and delegating roles. … I also think that I am organised, which helps me to be a team leader." Student G*. Under Levin's definitions this would fall into Managerial Awareness rather than Leadership but clearly at this stage of their learning students equate decision making and organisation with leadership rather than the more abstract definition of providing motivation and vision.

Table 1. Number of mentions coded as teamwork skills (for definitions see [9])

Situation Appreciation	1	Empathic Communication	8
Issue Oriented	3	Respectful Communication	22
Project Management	0	Negotiation	1
Research	8	Realistic Task Setting	0
Alternative Sources	0	Social Cohesion	4
Articulate Issues	0	Leadership	7
Objectives and Constraints	0	Team Support	8
Transferability	0	Facilitation	4
Team Feel	0	Collective Participation	0
Personal Resilience	1	Managerial Awareness	6
Social Sensitivity	1	Team Responsibility	2
Reflection	0	Other	31

The largest category is Other, which covers anything students have referenced that is not covered in Levin's skill set, including skills such as punctuality, work ethic, confidence, working under pressure - personal qualities which may make working in

a team easier but are much broader skills that are useful in a range of contexts. In particular, time management and meeting deadlines are mentioned a lot, not just within Other, but both are frequently referenced alongside other skills. However, the majority of references are in relation to the student only, *"My main strength would be I can always finish my work on time" Student AV*. Given more data from subsequent student projects or from student interviews, we may be the beginning of learning teamwork skills such as, Managerial Awareness, or Team Responsibility, or we may find that this coding structure needs to be modified to better reflect students' thinking.

Communication is a key skill for students, with the two communication categories, seeing the same number of mentions as Other. Students clearly feel that being able understand other team members' viewpoints as well as clearly communicate their own ideas is very important to successful teamwork.

Interestingly, skills such as Social Cohesion, Leadership and Team Support, skills that typically have a significant social aspect to them, are mentioned several times by students; noteworthy given the stereotype of the engineer as lacking in social skills.

3.2 What Did You Learn?

We took a thematic approach to the analysis of this question as students approached it in very personalised way. They mentioned skills that they had discovered or successfully improved as well as those that they had identified that need improvement in the future. Table 2, shows the main themes drawn from this data set.

Table 2. Skills that students have either improved or need to improve

Take Initiative	4	Confidence	12
Work Ethic	8	Punctuality	6
Organisation	4	Resilience	2
Balance	1	Big Picture View	4
Presentation Skills	3	Team Support	12
Communication	29	Leadership	6
Trust	2	Interpersonal Skills	8
Non-Specific	15		

A common theme in the reflections is that students had not realised that they had a particular skill or that their peers had recognised their efforts, *"I was surprised that [they] used this term [in the peer feedback] as I didn't think I was showing this skill" Student BG*. Students also mentioned that this reflective process was useful, *"This feedback made me take a step back and evaluate the week's work and how I have participated and worked" Student BM*.

Communication is a key area that students felt that they had either improved in or needed to improve it to work better within a team. This is part correlates with the previous question where communication skills were a common teamwork strength that students identified. Another key area that students identified are Interpersonal Skills and Team Support, again correlating with the previous question.

4 SUMMARY

Our initial results show that students have a relatively nuanced view of team skills in their first year of undergraduate study, with mentions of a broad range of skills. There are some clusters in areas such as Communication and Work Ethic but it is satisfying to see some understanding of the social aspects of team work, with mentions of more social focused skills, such as Social Cohesion and Team Support, bucking the stereotype of the engineer with limited social skills. Students found the teamwork experience and the structured reflection useful and were able to identify what worked and what needed improvement, hopefully feeding into the experiential learning cycle. Further work is need to gain insight into students' learning over time by linking students' progression over multiple project work experiences as well as increase the nuance our analysis to better reflect students' understanding of teamwork skills.

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COMPUTATIONAL METHODS FOR QUALITATIVE EDUCATIONAL RESEARCH: A HANDS-ON WORKSHOP

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1. *Interdisciplinary engineering education, linking different disciplines both inside and outside engineering, linking with society.*
2. *Niche & novel engineering education topics*

***Keywords**: computation, machine learning, visualization, education, research*

ABSTRACT

This paper is a background paper used in the workshop ID 203. This workshop will discuss how computational methods can support the analysis of qualitative data in educational research and will provide a hands-on experience for participants to use these methods. Computation enables researchers to process large amounts of data and represent complex phenomena in the form of interactive visualizations and computer simulations. Most of the development of a subdiscipline on computational educational research has been focused on using learning analytics and educational data mining, which often require large data sets. However, we argue that computational methods can also be used for smaller-scale educational studies using qualitative inquiry. Existing computational methods can be used to gain insight from complex qualitative data, and to automatically categorize and group/cluster records from a dataset (e.g., student approaches to an open-ended task, teacher responses to an interview, documents), and to validate the outcomes from a research study. In this workshop, the research team will share different approaches to use these methods, with sample studies they have conducted over the last eight years, and a hands-on R programming activity to use these methods. The workshop participants will leave with curated machine learning and data visualization workflow tools that they can use in their own research.

1 MOTIVATION AND LEARNING OUTCOMES

This workshop provides participants with a hands-on experience on how computational methods can support the analysis of qualitative data in educational research and provides a hands-on experience for participants to use these methods. After the workshop, participants will be able to: (1) recognize the value of using computational methods to support their research endeavours; and (2) use machine learning algorithms and visualization tools to better understand educational phenomena.

2 BACKGROUND AND RATIONALE

Computational science has become the third pillar of scientific discovery, along with the theoretical and experimental approaches. Computation enables researchers to process large amounts of data and represent complex phenomena in the form of interactive visualizations and computer simulations. Most of the development of a subdiscipline on computational educational research has been focused on using learning analytics and educational data mining, which often require large data sets. However, we argue that computational methods can also be used as supplements for smaller-scale educational studies using qualitative inquiry. Existing computational methods can be used to gain insight throughout the data analysis process including exploration, categorization, grouping and validaton stages. In the exploration process, the researcher may use visualization techniques to identify patters in the data. The researcher may also use authomatic natural language processing techniques to assign qualitative categories to the dataset. The qualitative categories can be turned into numbers to use clustering techniques for uncovering groups. Finally, statistical tests such as the permutation tests require computational power, but allows to validate findings with statistical significance.
For instance, Magana and colleagues [1] qualitatively analysed students' computational modelling process overa a think-aloud protocol using content analysis. Fig. shows how the authors created a visualization using the counts from the content analysis process, to then use kmeans clustering to group students based on the similar types of knowledge they used over this process.

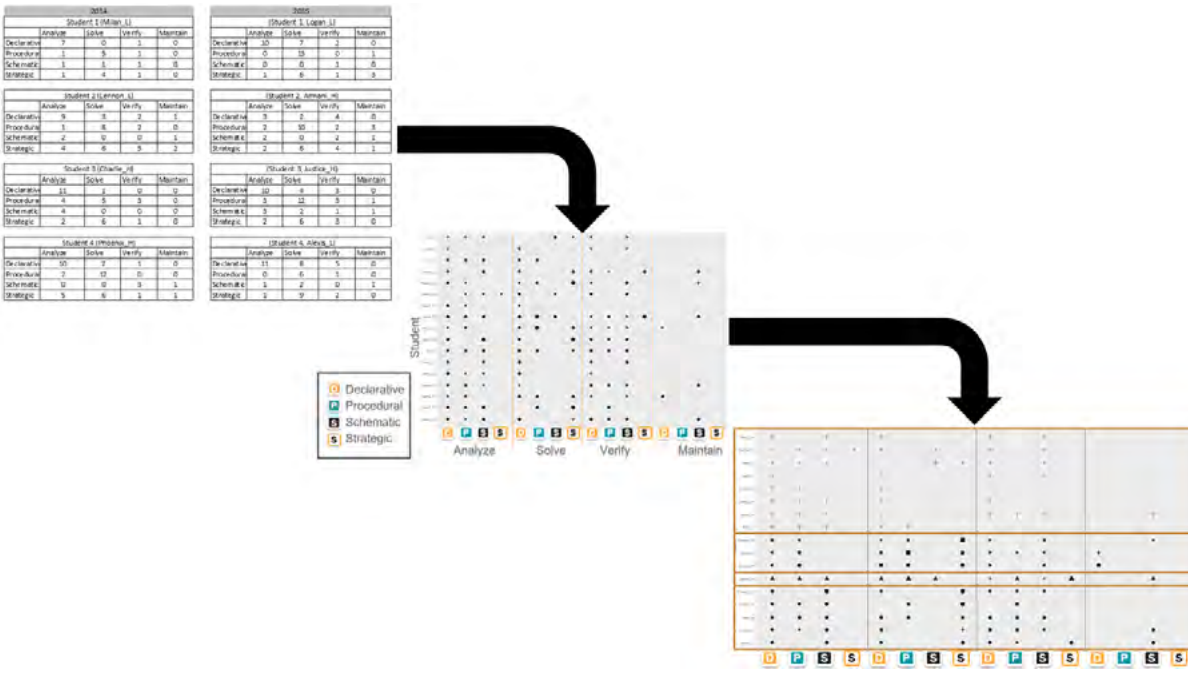

Fig. 1. Counts of content analysis to visualization to clustering

Similarly, Vieira and colleagues [2] analysed student written explanations of programming worked-examples to identify the different approaches students used to self-explain the example. They represented the resulting categories (columns) for each student (rows) in a heat map, and used hierarchical clustering with binary distance to group students with similar approaches (see Fig. 2)

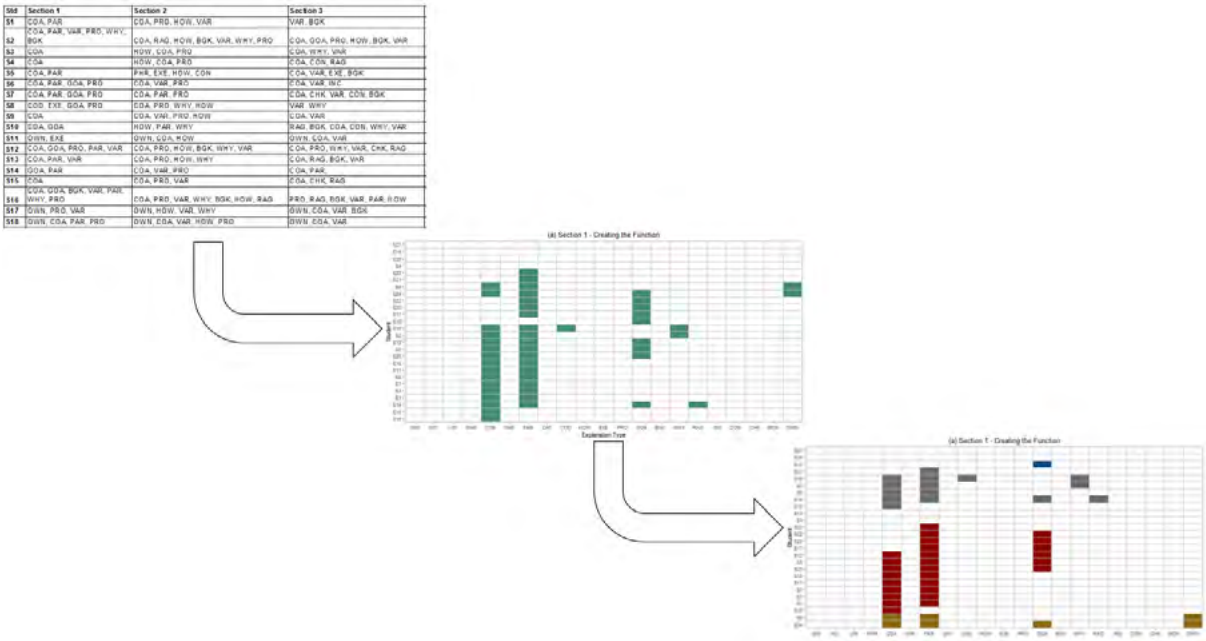

Fig. 2. Categories to visualization to clustering

Note that both examples used visualization and clustering techniques to analyse qualitative data with small sample sizes. However, each examples required of

different visualization and clustering techniques because of the nature of the data itself.

3 SESSION DESIGN

In this workshop, the research team will share different approaches to use these methods, with sample studies they have conducted over the last eight years, and a hands-on R programming activity to use these methods. The pedagogical foundation for the learning design of this study was guided by Cognitive Apprenticeship. Cognitive Apprenticeship [3][4] is a model that describes the components of learning environments that promote the development of cognitive and metacognitive skills. This model proposes the design of learning environments that merge "the content being taught, the pedagogical methods employed, the sequencing of learning activities, and the sociology of learning" [5] (p. 3). The implications for the learning design related to the organization of the sequence of instruction following the methods described on Table 1.

Table 1. Adaptation of cognitive apprenticeship methods for the pedagogical design.

Method	Definition (Collins et al., 1991)	Adaptation
0. Introduction (20 min)	The researchers introduced the different methods their uses to the participants. The participants are engaged in group discussion about how to analyse sample data sets. This step is not part of the cognitive apprenticeship model, but it is required for the workshop.	
Hands-on Activity (30 min): Workin in groups, the participants will use and modify sample implementations of the computational methods discussed in the introduction.		
1. Modeling	Consists of an expert's performing a task so that the students can observe and learn from the process that are required to accomplish the task.	Providing an expert's solution in the form of a worked-out example in an online interactive notebook.
2. Coaching	Comprises of providing opportunities to carry out the task and offering hints, reminders or feedback.	Allowing participants to use the expert's computational model to solve a educational research phenomena introduced at the beginning.
3. Scaffolding	Includes providing supports to help the students to carry out the task.	Providing templates of code that provide the basic functionality coupled with in-code comments that guide the participants in implementing the critical functionality

4. Articulation	Involves engaging students to articulate their knowledge, reasoning, or problem-solving processes.	Asking participants to provide in-code comments to their own solutions where they will connect the disciplinary problem with a computational solution
5. Reflection	Encompasses enabling students to compare their own problem-solving processes with that of an expert.	Providing test cases so participants can validate their own computational solution.
6. Exploration	Involves eliciting students to engage in problem solving on their own.	Eliciting participants to adapt the new implemented computational model to solve a new problem.
Reflection (10 min): How can we use these methods for our own research?		

The workshop participants will leave with curated machine learning and data visualization workflow tools that they can use in their own research. For instance, Fig. 3 and Fig. 4 depict a section of two different R Markdowns (i.e., websites with executable blocks of codes, that serve as interactive notebooks). Fig. 3 shows an example of visualizing patters in a systematic literature review.

Code Start Over Run Code

```
myPlot <- ggplot(litReview, aes(x=CET, y=SoV))+
  geom_count(aes(color=Venue))+
  scale_x_continuous(breaks=seq(0, 10, 1), limits=c(0, 10))+
  scale_y_continuous(breaks=seq(0, 10, 1), limits=c(0, 10))+
  scale_size_continuous(breaks = seq(0, 5, 1))+
  labs(title="Two Dimensional Comparison",
       subtitle="Gap between Education and Visualization Researchers",
       y="Sophistication of the Visualization",
       x="Connection to Educational Theories",
       size="# of Studies")
myPlot
```

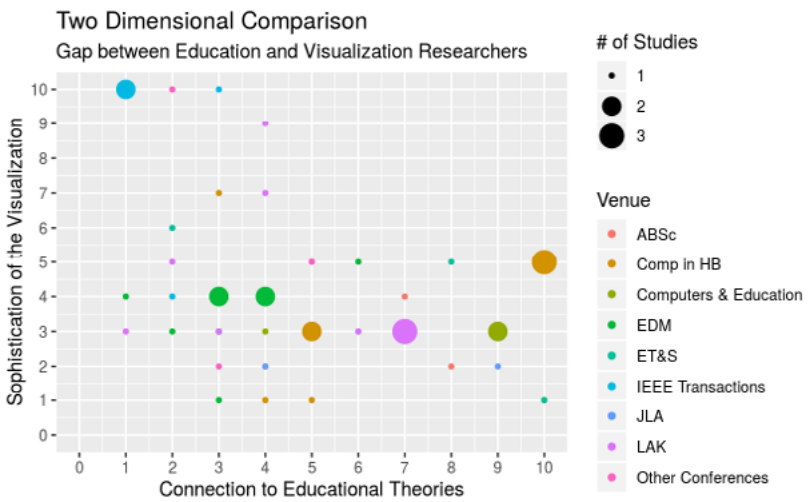

Fig. 3. Sample Code Block and Resulting Execution on https://cvieiram.shinyapps.io/plotsLitReviewAPG

Fig. 4 shows a scatter plots with sample data that is used to explain the kmeans clustering algorithm.

Question: Do you see any patterns in the plot?

Code Start Over Run Code

```
ggplot(iris, aes(x=Petal.Length,y=Sepal.Length))+
  geom_point()
```

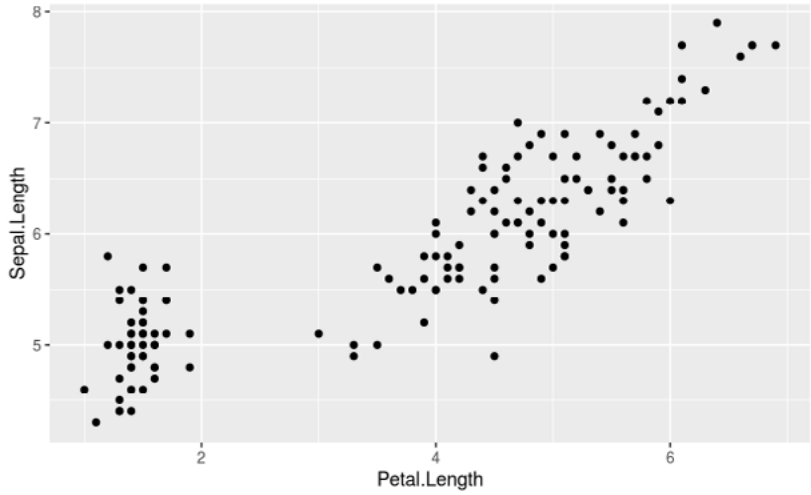

Fig. 3. Sample Code Block and Resulting Execution on https://cvieiram.shinyapps.io/unsupervisedAlgorithms/

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WORKSHOPS

ORDERED ALPHABETICALLY BY FIRST AUTHOR

GARDENING WITH THE LIVING TEXTBOOK

NAVIGATION VIA LEARNING PATHWAYS AND A CONCEPT MAP

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Keywords: *Digital textbook, ontology, concept map, learning pathways, learning analytics*

Description

This workshop introduces the Living Textbook (LTB), an ontology-based textbook, developed by the ITC Faculty of the University of Twente. The LTB shows a combination of a concept map and a wiki with additional learning functionalities. Students can study the learning material by browsing the concept map, clicking on the concept of interest, and read the text related to the concept. Additionally, learning pathways are defined by the teacher that linearly connect several concepts. A third way to go through the material is by clicking on hyperlinks to specific concepts offered in the learning management system used in the course.

In their minds, teachers often see a concept map of the topic they are teaching. This concept map is constructed of concepts and relationships between these concepts. It usually contains hierarchies (higher-order versus lower-order concepts). It would be useful to share this concept map with students, yet this is rarely done. Seeing the concept map and understanding the relationships between different concepts can lead to deeper learning (Davies, 2011). Concept maps are often difficult to teach with, as Davies (2011) states: "*The main disadvantages of concept mapping are that they require some expertise* to learn". Students more often do not have this expertise.

We present content to our students in textbooks that are often sequentially structured. These textbooks have the advantage of easy navigation but do not allow to see the links between topics that are presented in different chapters. Knowing that

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a visual representation can help us to reach a higher level of understanding, this is a missed opportunity. The LTB offers the possibility to study non-linearly.

Participants in this workshop will explore the LTB functionalities, including the learning pathways, concept map, and the learning analytics dashboard. The main focus of this workshop will be on different navigation methods using either a concept map or sequential learning pathway. Participants will follow different navigation strategies. Via the chat functionality, participants will be asked to open the LTB during this workshop.

The workshop will start with a short presentation about the Living Textbook project and will provide an overview of the different courses in which the tool has been implemented so far. We will introduce the main concepts and structure of the LTB. A short (live) demo will be given to show the participants how to log into the LTB software, to find a study area, and to the different navigation methods. Then the participants can work hands-on with the LTB. They will be placed in the role of a student and will be provided with a number of questions that will require navigation via both the Sequential learning Pathways and the free Concept map exploration. The workshop will end with a review of the learning analytics dashboard (live demo) and a discussion on the current implementation and possible further work. A specific topic during this discussion will be the usability and extensibility of the system from an academic's perspective. A true concern about the implementation of the LTB is the expected amount of work involved in implementing such a system. We like to hear suggestions from workshop participants on this point. Participants will be asked to fill out a questionnaire at the end of the workshop to describe their experiences and will be invited to test the software further.

This workshop is linked to a paper on learning Analytics using the LTB presented during the SEFI conference.

Room/Equipment needs:

Not applicable.

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SUSTAINABILITY, RESPONSIBILITY AND ETHICS FOR ENGINEERS - AN INTERACTIVE AND TRANSFERABLE COURSE SYSTEM

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The Blue Engineering course design promotes socially and ecologically responsible engineering through a variety of alternative teaching methods. Engineering students acquire the competence to unveil the complex interdependency of their social, political, ecological and economic surroundings. This includes the consideration of different values, interests and needs within a global perspective as well as within one class(room). The course design encourages democratic decision-making not only to solve but also to define problems within the course itself and moreover outside of the classroom. The course design is successfully implemented at seven universities in Germany reaching over 300 students each semester. This underlines the high adaptability and transferability of the course design. Thus, participants of the workshop will experience first hand a course design that may be easily adapted to any engineering study program. To underline the student-driven approach of the course design, the proposed 40-minute workshop will be conducted entirely by student tutors. As a backup, senior faculty will also attend the workshop which consists of three parts: 1) teaching/learning in practice, 2) implementation of the course design at different universities, 3) adaptation and transferability of the course design to other universities.

WORKSHOP PROGRAM

1) 10 Minutes - The workshop participants will engage in a set of interactive teaching/learning units in order to gain an immediate methodological and content-related impression of the course concept
2) 10 - Minutes - The implementation as well as the transferability of the course concept will be demonstrated using the examples of TU Berlin, University of Applied Science Düsseldorf and Technical University of Applied Science Köln. This includes the presentation of the experiences based on a the digital implementation of the course during the Corona pandemic.
3) 20 - Minutes - The final discussion will focus on the conditions for successful adaptation and transfer to other universities and disciplines. The discussion will be

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sparked as a short role play in small groups where the participants take up the different roles at a university in order to identify drivers, barriers etc.

LEARNING OUTCOMES OF THE BLUE ENGINEERING COURSE

The description of the learning outcomes of the course follows a design down process, which means that the learning outcomes on the higher educational levels function as guidance to derive the learning outcomes on the lower levels. For this, the 12 broadly recognized sub-competences of Gestaltungskompetenz of an education for sustainable development have been reformulated as learning outcomes. Next, they were adapted as specific learning outcomes for the course. These learning outcomes are already specific enough to constructively align with the broad range of learning activities of the course as well as with the formative assessment of the students. Furthermore, this precisioning allows for a comprehensive evaluation of the whole course.

DESIGN OF THE COURSE ON SUSTAINABILITY, RESPONSIBILITY AND ETHICS FOR ENGINEERS

The course is a student-initiated course design that addresses the social and ecological responsibility of engineering. Its student-driven character is achieved through a set of over 150 well-documented teaching/learning units which are freely available online. The course consists of three parts so that the students gradually acquire the competences to co-conduct and co-develop the course: 1) Students get to know high quality teaching/learning units conducted by a lecturer/student tutors; 2) Students conduct existing teaching/learning units; 3) Students develop new teaching/learning units and conduct them as wells document them for future use.

TEACHING/LEARNING UNITS OF THE COURSE

Key element of this student-driven design is a set of 15 to 90 minute long teaching/learning units. Each unit must provide an appropriate set of methods to enable any generally interested group with a maximum of 25 persons to acquire a certain insight into the ecological and social dimensions of technology. In order to reach this goal, these teaching/learning units are self-contained units that cover one specific topic and that provide different methods that engage the participants in co-conducting a lesson more or less by themselves. Therefore, the person conducting the teaching/learning units does not function as an expert that simply conveys knowledge but as a facilitator that organizes a complex group process.
The over 100 teaching/learning units cover a broad range of topics within the field of social and ecological engineering. Some of these teaching/learning units help to thoroughly analyze single technologies, e.g. fracking, preimplantation diagnostics, while others address the general effects of technology on society or nature. There are a number of unis which address the individual sphere, e.g. mobility and consumption while other unis address the global sphere, e.g. agricultural industry, capitalism, climate change. Several unis particularly address the work-life of engineers and the concept of work in general.
Along with the wide variety of topics, every single teaching/learning units uses a specific set of teaching formats such as case studies, storytelling and station learning. Most teaching/learning units, however, rely on a specific adaptation and new combination of known methods, e.g. learning cascades, court trials and educational games. Thus they make extensive use of methods that take the shift

from teaching to learning seriously, e.g. role play, station learning, crime scene investigations and educational games.

IMPLEMENTATION OF THE COURSE AT SEVEN UNIVERSITIES

The Blue Engineering course is currently conducted each semester at seven universities in Germany. Here, student tutors are in charge of running the entire course as they are only coached and supervised by faculty members. In total, over 300 students attend the courses each semester and over 1500 student have successfully passed the course over the past semesters.

The different implementations show that the course design is highly adaptable to different settings. Typically, the course is a compulsory elective in a number of study programs within the engineering faculty, e.g. mechanical engineering and industrial engineering. In addition, an initiative has been taken up at one university to also include non-engineering study programs such as economics and informatics. Overall, this setup ensures a learning experience that crosses disciplinary borders allowing an interdisciplinary approach to learning/teaching.

DESIGN OF CHALLENGE BASED EDUCATION: EXPERIENCES WITH INTRODUCING CBE IN THE ECIU UNIVERSITY

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Conference Key Areas: *Interdisciplinary education, Challenge based education, Maker projects*
Keywords: *Challenge based education, flexible education, cooperative learning, European university, changing role of teachers*

ABSTRACT

Background

With new knowledge developing at an ever higher speed and problems crossing boundaries more and more (both disciplinary as well as nationally), future graduates need to be able to solve multidimensional problems in at least multidisciplinary teams while adjusting to this continuous and rapid change.
Many parties already call for a change in engineering education, for more interdisciplinarity, with more individual learning paths, greater focus on 21st century skills and more learning skills (Goldberg & Sommerville, 2014; Graham 2018; OECD 2018; Elearning industry), which stimulates students to develop adaptive expertise (Taylor, 2007; Bohle Carbonell, 2014). Challenge Based Education is an educational approach that can help engineering students develop these competencies (Taylor, 2007; CBL).
In line with their motto (and ambition) to challenge conventional thinking about education and in response to the EU call for creating European Universities (EU, 2017), the European Consortium of Innovative Universities (ECIU) founded the "ECIU University". Core of the ECIU University is Challenge Based Education (CBE).
CBE is a learner centered approach that gives opportunity to individual learning outcomes. It brings together learners, faculty, and stakeholders from across society to work on relevant global challenges, while at the same time aiming to find a solution which is environmentally, socially and economically sustainable and has real, local impact (Kohn Rådberg et al. 2020, p 22). Multidisciplinary teams of learners work together to follow three different phases: *Engage*, *Investigate*, *Act* to solve the challenge (CBL).
During the *Engage* phase, the team starts with the Big Idea, the challenge that is relevant for the individual learner and society. Based on this, the team defines Essential Questions, important problems that follow from the Big Idea. Elaborating on

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these Essential Questions, the team decides on an actionable Challenge Statement, the problem they will be working on.
During the second phase, *Investigate*, the team starts with Guiding Questions to find out what they need to learn about the challenge statement in order to come up with a plan how to find an appropriate solution. During the Guiding Activities the team finds new sources and learns more about the topic. During Synthesis the team combines all newly acquired information.
In the final *Act* phase, the team starts with Solution Concepts, different ideas to solve the problem. In the Solution Development they develop the solution they think will work best. Implementation and Evaluation then follows where the team actually implements the solution, evaluates its working and if necessary improves upon it. Important to notice is that throughout the whole process, the team members continuously document and share their experiences, and reflect on their own actions and learning. It is crucial, that the last step of a CBE-project is reflection on the learning and working process.

LEARNING OBJECTIVES OF THE WORKSHOP

In this workshop, the participants will learn how the different phases of CBE are done, by working on a challenge themselves. As the challenge is about introducing CBE in a university, they will also learn about what is needed to implement CBE in their own programme. Examples and resources will be available, so the participants will learn from these as well.

SET UP OF THE WORKSHOP

At the start of the workshop, participants will discuss the challenge given to define the essential questions. They will then be divided into small multidisciplinary groups, to further elaborate on different actionable challenge statements. In the small groups they will go through the different phases of CBE, and will receive support when necessary. At the end all subgroups will share their ideas with the whole group which will be summarized, so every participant will have a complete overview of ideas on how to introduce CBE.
To make the workshop interesting for all participants, we would like to have between 12 and 30 participants.

EVALUATION OF LEARNING RESULTS

After the presentations of the subgroups, the participants will reflect on their own experience, write down their lessons learned and additional questions. We'll ask several participants to share their experiences.

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FOCUS ON SELF-DIRECTED LEARNING: THE LEARNING AND ASSESSMENT PHILOSOPHY OF THE UNIVERSITY COLLEGE TWENTE

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Conference Key Areas: *Future engineering skills, Niche & Novel*
Keywords: *Self directed learning, self evaluation, reflection, feedback, new engineer*

ABSTRACT

Background

Developments in modern engineering have led to new materials and production technologies, and as a consequence, new designs that can no longer be attributed to single fields of engineering. Today's breakthrough technologies cross traditional borders between classic fields of engineering and extend to business and social sciences. Innovations emerge from surprising and unpredictable combinations of classic fields, raising questions for engineering curricula. Modern engineering solutions require not only technical but also social perspectives and understanding. They require an integrated socio-technical perspective and an understanding of how technical solutions function in the real world. They require engineers who can identify connections across boundaries between disciplines and see interrelatedness of problems and solutions across different fields. In addition, with changes in the world taking place at an ever-increasing speed, future graduates can no longer rely on their education to be sufficient throughout their career, they will need to update their knowledge and skills continuously.

These developments in turn mean that higher education needs to adapt, with more focus on interdisciplinarity, broader skills (or 21st century skills), flexibility, and learning skills (Goldberg & Sommerville, 2014; Graham, 2018; OECD, 2018; Morris, 2019). Goldberg & Sommerville (2014) even call for educating a whole new engineer.

The ATLAS programme of the University College Twente is educating this new engineer, giving students a broad multidisciplinary project-based education with a combination of natural science/engineering, social science, and mathematics. As teaching philosophy the programme has embraced the concept of self-directed learning (Gibbons, 2002; Saks & Leijen, 2014; Morris, 2019). The individual

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academic development of students lies at the heart of the curriculum. Apart from ensuring an academic foundation, the programme is not based on a specific set of prescribed courses, nor on curriculum requirements, nor on restrictions. ATLAS students are encouraged to explore academic opportunities within and beyond what is offered by the programme.
The students develop their own learning plan with a description of what they want to learn and how, called a Personal Development Plan (PDP). Much is possible, as long as it meets the minimum academic requirements as set out in the general Intended Learning Outcomes of each semester. Students choose their own method of learning, either by following courses offered in the ATLAS programme, courses from other programmes at the University of Twente or other universities, or online. Cooperation is encouraged in all semesters: ranging from groupwork in the semester projects of the first two years, to peer-learning in the theoretical courses. At the end of each semester the students reflect on what they have learned, substantiating their claims with evidence, in their Self Evaluation Report (SER). This SER is the basis for the assessment, and the assessment and feedback on the SER again serve as a source of input for the next PDP. Students are supported in writing their PDP and SER by personal mentors, different workshops on self-directed learning, examples of previous years, and individual feedback.
In this workshop the participants will experience this PDP-SER cycle themselves, and will learn how more focus on self-directed learning can help improve (engineering) education to better prepare graduates for their future work life.
Learning objectives of workshop
In this workshop we will not only explain how the PDP-SER cycle works in the ATLAS programme, but participants will go through their own PDP-SER cycle as well, thus experiencing what this PDP-SER cycle is and how it works. Furthermore, the participants will learn what is needed to implement (parts of) such a system in their own programmes.

Set up of the workshop
At the beginning of the workshop, all participants will write their own Personal Development Plan, to translate the workshop's objectives into personal learning objectives. We will continue with an assignment which lets the participants experience the effect of self-determination in assessment. We will then explain how the PDP-SER cycle works in the ATLAS programme, what we do to make it work for students and discuss our experiences. Next, the participants will work in small groups on applying the lessons from ATLAS to their own programme. To guarantee that participants can learn from one another and at the same time can contribute individually, we would like to have a minimum of 12 and a maximum of 20 participants.

Evaluation of learning results
We'll conclude the session with an evaluation of the findings of the different groups, to share experiences of applying the insights on their own programme. Furthermore

we will reflect on the lessons learned, both as a group as well as individually. For the latter, the participants will write their own SER, which guarantees that they will have concrete lessons to take home, to implement in their next PDP.

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SMARTPHONE-ASSISTED STUDENT FEEDBACK TO LECTURERS FOR BETTER ENGINEERING EDUCATION

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Conference Key Areas: *HE & Business, Career support, Engineering in schools*
Keywords: *lecture quality, student feedback, digital tool, improvement*

ABSTRACT

One way to work on improving engineering education is to collect and use student feedback about lecturers' teaching quality. However, as a lecturer in engineering education, it is not always easy to obtain such feedback. Therefore, the Impact! tool was developed. Students fill in a short questionnaire anonymously right at the end of the lecture just delivered. The questions reflect scientifically investigated characteristics of effective lessons. Summaries of students' ratings are provided to lecturers. This way, student perceptions could be an important basis for lecturers' reflections on their teaching and, how their lectures can be improved. Workshop participants will experience using the Impact! tool and we will discus how student feedback can be used effectively for improving engineering education. Moreover, results of research into the use of the impact tool will be presented and discussed.

1 INTRODUCTION

A goal of the Quality Agreements of the University of Twente is to improve the quality of (engineering) education. Therefore, normally student perceptions are collected regarding the quality of a whole course that has ended. However, there is much time between receiving the results and the start of next year's course. Moreover, the feedback is often about the *overall* course quality, what causes problems if a course is delivered by more than one lecturer. The digital feedback tool 'Impact!' makes it possible for lecturers to obtain feedback from students right at the end of each lecture, in a few minutes. The feedback gives lecturers insight into the strengths of their lecture, and into areas where improvement is possible. Lecturers thus can work on improving their follow-up lectures immediately. The students of that course can directly benefit

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from that (rather than providing feedback at the end of a course, when it is too late to improve this year's course).

The Impact! tool was initially developed for use in secondary schools. Because of its success, we developed and tested a version of the tool for university lectures. Lecturers used the tool during a pilot in their lectures, to obtain student feedback as a basis for improving their teaching. The student feedback they obtained was found to be relevant for improving follow-up lectures, especially for starting lecturers. The tool is being implemented at a larger scale within three faculties of the University of Twente.

2 WHAT ARE SESSION PARTICIPANTS EXPECTED TO LEARN?

In this digital workshop, we will present the content and the features of the Impact tool. Participants will experience using the tool. Furthermore, research findings and recommendations for the implementation of Impact! in engineering education will be discussed with the audience as well as preconditions for improving lectures based on student feedback.

3 WHY IS THE SESSION RELEVANT?

The digital 'Impact!' tool provides lecturers with student feedback about the degree to which their lecture that just ended meets the characteristics of effective lessons. Because the feedback is sent to the teachers right after the lecture, the link between their actual teaching in the lecture and the feedback received can be made better, than in the case of general feedback at the end of a whole course. In the workshop, participants will discuss possible implementations of students feedback by means of the Impact! tool in their own educational practice.

4 HOW ARE SESSION PARTICIPANTS ACTIVATED?

Participants will experience using the tool. They can easily do this with their own smartphone when they are joining the workshop at home. By using the digital brainstorm tool 'Padlet', research findings and recommendations for the implementation of Impact! in engineering education will be discussed with the audience.

5 TAKE HOME MASSAGE FOR SESSION PARTICIPANTS

Student feedback by means of the Impact tool can encourage and support lecturers to improve the quality of their lectures. We know that a sustainable improvement of lecture quality requires more than only obtaining feedback: clear support on what and how to improve, and sometimes also coaching during the improvement process are important for improving lectures.

6 HOW IS THIS WORK SIGNIFICANT FOR ENGINEERING EDUCATION?

This workshop shows a practical way how to collect and use student feedback within the context of engineering education in-between lecturers. As such, it will be an interesting workshop for lecturers working in engineering education as they can experience using the Impact! tool and will learn about the relevant preconditions for

using student feedback in such a way it will affect their own lecturing in an effective positive way.

COACHING ENGINEERING ETHICS EDUCATION RESEARCH

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Engineering ethics education still faces many challenges, such as specification of what it really wants to address, how to truly engage and motivate engineering students for ethics education with activating methods or how to assess important ethical goals such as being a critical citizen or fostering moral awareness. There is a need for more and more evidence-informed Engineering Ethics Education Research to support answering these challenges.

The aim of the workshop is to address this need. As it is organized by members of the SIG Ethics, it will be one step in coaching participants to elucidate together what good research in engineering ethics education entails and to enable the SEFI community to pursue research in this area.

The online workshop will have the following structure: (1) Intro of the topic. (2) Collection and prioritization of important challenges in engineering ethics education. (3) Participants will be divided in small groups working on a topic of interest in online breakout rooms. (4) An experienced reviewer/editor gives some core recommendations on conducting research in engineering ethics education (5) Small groups come up with a first research proposal: problem description, theories to be used, research question, limitation of scope and research method. (6) The different groups present their proposals and get feedback from other groups.

The SIG Ethics will organize an event taking place between the yearly SEFI conferences of 2020 – 21 in order to continue to work on these paper proposals. As such, the workshop is a first step in an output oriented process of coaching Engineering Ethics Education Research.

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BEST PRACTICE FOR EMBEDDING THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS IN ENGINEERING EDUCATION PROGRAMS

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This workshop proposal is submitted by the SEFI Working Group on Sustainability following a discussion on the topic at the working groups' meeting at the conference in Budapest in 2019.

Purpose and background

The purpose of the workshop is to discuss the nature of 'best practice' for how to translate the United Nations' Sustainable Development Goals (SDGs) into educational practice. Today, many engineering education programs (EE programs) work with topics that are sustainability-related. For example, developing better city infrastructure, renewable energy technology, efficient public transportation, sustainable food ingredients, etc. The United Nations' SDGs make the concept of sustainability tangible and allow individual EE programs to both explore and select which SDGs their students and graduates work with during their education and careers. Using the SDGs, EE programs can find their particular role in ensuring an inhabitable planet for future generations. In addition, the SDGs enable increasing sustainability ambitions in EE programs, for example by including sustainability-related learning objectives into a program or by engaging deeper into those sustainability-related learning goals that naturally lie within the scope of a program's discipline.

Target audience

The core target audience consists of three groups: (1) leaders of individual EE programs, (2) university department heads and deans of education, and (3) members of university committees at all levels, who are tasked with embedding sustainability in engineering education. Leaders of individual EE programs,

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department heads and deans of education all participate in EE program development, which includes formulating visions for the future. Once visions and future objectives are formulated, the next step is implementation. Implementation may happen 'through the line' or by establishing specifically tasked committees. Members of such committees are often faculty members, but may include staff positions, researchers, and practitioners as well.

Workshop learning outcomes

The workshop brings wide-ranging experiences and practices to the surface. Workshop participants will get to know current practices for SDG-implementation in EE-programs, which they can bring back with them to their home universities. The workshop provides basis for networking and getting to know peers, who work with the same challenges.

In addition, participants will take part in shaping future practices for embedding sustainability as an integral component in EE programs. The participants of the workshop will contribute not only to the dialogue in the (online) room, but also to the wider discussion of sustainability in engineering education that takes place at home universities following the SEFI conference.

Key questions for the workshop

During this workshop, we will discuss how EE programs and EE institutions can best work with the United Nations SDGs. The following three questions are key in these discussions:

- What constitutes 'success' for SDG-integration of in EE programs? What are the success criteria?

- How can instructors and EE program leaders embed the SDGs as component parts in EE programs? What are the enablers and requirements?

- How can EE institutions support and organize efforts of embedding the SDGs in EE programs? What are the enablers and requirements on an institutional level?

Workshop procedure

The procedure detailed below will work well with both few or many participants. With more than four or five participants, we will conduct the body of activities in parallel groups, each with their own facilitator.

1. Facilitators welcome everyone to the workshop and introduce objectives and procedure. Duration: 5 minutes.

2. Workshop participants read two short examples of how SDGs are embedded in an EE program. One example focuses on embedding SDGs in individual EE programs while the other focuses on support and organization of institution-wide efforts of embedding SDGs in EE programs. Duration: 5 minutes.

3. Participants are asked to reflect on the two examples as well as their own experiences and practices. A few practices from participants are shared orally. Duration: 15-20 minutes.

4. From all included experiences and practices, participants are asked to identify (a) success criteria, (b) requirements, and (c) enablers of integration of SDGs in EE programs. Participants summarize their reflections in writing*. Duration: 10-15 minutes.

5. Reflection notes are organized in subcategories by the facilitators. Duration: 10-15 minutes.

6. The facilitators summarize conclusions and learnings about best practices. Duration: 5-10 minutes.

* Reflections are written down under the three headlines (a) success criteria, (b) requirements, (c) enablers, and (d) none of the above

The next step after the workshop

The outcomes of the workshop can contribute to position papers and opinion pieces in engineering education journals and conferences. Some learnings may be particular to certain disciplines (e.g. software engineering or civil engineering only) while other learnings are transferable to all EE programs. The focus of the workshop is learnings that are transferable to wider groups of EE programs.

THE FUTURE OF CONTINUING ENGINEERING EDUCATION IN THE ERA OF DIGITALIZATION AND PERSONALIZATION

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Conference Key Areas*: Future engineering skills and talent management Engineering curriculum design, challenge based education, maker projects, use of professional tools.*
Keywords*: continuing engineering education, lifelong learning, upskill and reskill, professional development*

ABSTRACT

The pace of introduction of new technology and thus continuous change in skill needs at workplaces, especially for the engineers, has increased. While digitization induced changes in manufacturing, construction and supply chain sectors may not be felt the same in every sector, this will be hard to escape. Both young and experienced engineers will experience the change, and the need to continuously assess and close the skills gap will arise. How will we, the continuing engineering educators and administrators will respond to it?

Prepared for engineering educators and administrators, this workshop will shed light on the future of continuing engineering education as we go through exponentially shortened time frames of technological revolution and in very recent time, in an unprecedented COVID-19 pandemic.

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WORKSHOP FOCUS

Traditionally, professional engineers and technologists have practiced a structured path for advancement in career, thus continuous professional development for those engineers has followed structured curriculum and pathway. However, during Industry 4.0, an era of digitalization – artificial intelligence, data analytics, and blockchain --, does it look the same? Or, during the yet to arrive Industry 5.0, which is predicted to be the era of personalization and focus on humans and machine cooperation, how will the path of continuous professional development of the professional engineer look like? Will the engineers ever stop learning? Will they continuously have to reskill to cope with the ever-changing technology-based workplace or simply upskill to move forward?

As we are experiencing the consequences of the COVID-19 pandemic, we are asking ourselves, what knowledge and skills that the industry will need in the post-pandemic world? Will it radically change from pre-pandemic need? Will the industry change so rapidly over the next few years that the engineers will need to reskill and upskill themselves continuously? Will academia be able to prepare the students for a life of continuous learning?

The workshop participants will critically assess –

- the skills that the industry will require from the engineers in entry level and later
- how the industry and academia collaboratively can develop continuing engineering education curriculum to address such needs, and
- how the industry and academia collaboratively can prepare the students for a lifetime of learning.

WORKSHOP METHODOLOGY

Before the Workshop

Before the workshop, the participants will be requested to read a number of web-based freely available articles and international reports focused on the future of work and learning, as cited in the References [1, 2, 3, 4, 5]

During the Workshop

This workshop aims to gather practitioners in the field of lifelong learning in engineering to brainstorm several paths for closing the obvious skills gap, rapid curriculum development, and deployment via accessible formats, flexible learning modes and paths, assessment, learning outcome evaluation and recognition, accreditation, and personalization.

The 80-minute virtual workshop will be divided into six sections:

1. Presentation on the current situation of work and learning [Main Virtual Room]
2. Brainstorming discussions in groups on the possibilities during Industry 4.0 – Digitization [Breakout Virtual Rooms]
3. Presentations on the future of work and learning [Main Virtual Room]
4. Brainstorming discussions in groups on the possibilities during Industry 5.0 – Personalization [Breakout Virtual Rooms]
5. Presentation by each group [Main Virtual Room]
6. A list of work to do by the participants, as the workshop outcomes are summarized. [Main Virtual Room]

After the Workshop

At the end of the workshop, participants are expected to experience the following learning outcomes:

- A thorough knowledge of the current and future scenario of work for engineers
- how engineering education will need to incorporate a lifetime of learning mindset
- a framework developed by the participants themselves on how continuing engineering education learning communities will shape in the future while remaining agile in nature.

Based on the workshop outcomes and group presentations, we will explore the possibility to write and submit a proposal together with the participating attendees for the new European subsidy programs.

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GUIDING UNIVERSITIES TO DEVELOP ENGAGING K-12 OUTREACH PROGRAMS

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Conference Key Areas: *Interdisciplinary education; Challenge based education, Maker projects*
Keywords: *Outreach, K-12, Engaging, Hands-on*

ABSTRACT

At the Massachusetts Institute of Technology (MIT), the student learning experience is informed by a "Mens et Manus”-style pedagogy with hands-on, learning-by-doing activities that complement the many facets of engineering education that happen around the Institute. However, this mindset is not only relegated to the engineering disciplines as courses in the sciences, mathematics, humanities, arts, and social sciences also implement tenets of this style of instruction. As a result, the permeation of this learning-by-doing spirit also shines through in the activities and initiatives that take place outside of the classroom. For example, MIT programs like Global Teaching Labs (GTL), MIT International Science & Technology Initiatives (MISTI), the Abdul Latif Jameel World Education Lab (J-WEL), and STEAM Camps give MIT students the opportunity to teach and share MIT's unique approach to education with partner schools around the world.

Although MIT’s main focus is college-level education, there is a great understanding of the importance and growing interest towards transforming and enhancing K-12 level education at both the administration and faculty levels. Developing new

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resources but also by attempting to transmit MIT's core values to the K-12 system, MIT has a long history of K-12 outreach programs, with a particular focus in both STEM and STEAM education. Our proposed workshop focuses on how universities and institutions of higher education can utilize the resources and talent within their institutions to develop outreach programs and initiatives aimed at engaging K-12 learners and educators. As citadels of both culture and knowledge, universities are in the best position to transform and have lasting impacts on both educators and younger students. In our workshop, we will discuss our approaches for how to create offerings that are initiated by university faculty, students, and staff. By taking participants through a design thinking exercise devised to have academics consider deeply how the work they do can contribute meaningfully to the experiences of a K-12 student.

With a strong K-12 community, we have found that many groups can collaborate to meet the needs of different types of learners. For example, MIT's pK-12 community often finds diverse ways to work together in new efforts, stemming from a recognition of various groups' areas and levels of expertise. This community of practice pulls participation from multiple departments, labs, centers, and student-created groups, stretching across faculty, staff, and both the undergraduate and graduate populations. Similarly to the definition of community of practice by Wenger (1998), the members of our K-12 community share similar values and beliefs about learning and about finding ways to continue to refine and improve what we do in benefit of learners and educators. There is even more to discuss regarding the ways that higher education institutions can be a positive resource within our current world climate. With the massive impact that the spread of COVID-19 has had around the globe, we, as centers of learning, have all had to make significant modifications to the ways that we interact with learners, including the K-12 educators and students who have all been relegated to their homes throughout 2020. Two additional efforts that we plan to reference include an adaptation of a week-long in-person set of events that transformed into a remote, six-week seminar focused on designing learning experiences and a collection of curated resources for K-12, higher education, and workforce learners meant as a rapid response to the need for online resources during the pandemic. Both were modified and adapted over the course of a few weeks and can serve as examples to demonstrate how a university can continue to have positive and engaging effects on K-12 education from a distance.

In our proposed 80-minute workshop, we intend to take participants through a process that will explore their own work and consider pathways that can be taken to make stronger connections with those who work within K-12 contexts. Relevant questions discussed will include:

- What existing efforts to connect to K-12 populations take place at your universities?
- How does the K-12 outreach community come together at your institution (if at all)?
- And what are the things you think you could be doing that you're not?

We will discuss our approach for creating opportunities and also for connecting both university students with faculty and staff to support diverse communities of learners as well as the underlying motivations for why an institution of higher learning may want to pursue connecting with younger learners at all. Along with this we will bring examples of both what has worked and not worked so well in our experiences with outreach. In lieu of the current COVID-19 situation, we also plan to address and advise on practices we have tested for creating engaging remote online learning experiences. We hope during this workshop, participants will share ideas that have sparked their interest and join in a discussion on how universities can come together as a force in engaging with K-12 education. Expected learning outcomes will include learning about our framework for identifying and supporting existing university K-12 outreach programs as well as the development of strategies to foster stronger relationships between universities and K-12 learners. Ideal participants will include faculty members, university leaders, and policymakers but teachers and students may also find benefits from attending.

REACH THE NEXT LEVEL IN BLENDED EDUCATION; A HANDS-ON EXPERIENCE WITH THE EMBED FRAMEWORK

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Topics: *E-learning, blended learning, virtual reality*
Keywords*: Blended Learning, Blended Education, European Maturity Model, Institutional Strategy, Implementation*

ABSTRACT

Introduction

Blended education has worldwide risen in popularity. A lot of institutions are implementing policies and conditions in order to organise and support blended teaching as it has been shown to be an effective approach for multidisciplinary, challenge-based education. By blending online and onsite learning environments, or combining virtual and physical makerspaces and labs, a rich learning experience can be created for students. Hence, an appropriate, futureproof formal higher education context is crucial for institutions to remain or become mature in blended courses and programs.

Yet, how may academic leaders assess their status of affairs regarding blended education? How can higher education institutions bring their blended education to the next level, and make sure that it keeps improving? These questions guide the present workshop. During the workshop a framework for systematic assessment and improvement of blended education is demonstrated and employed in a hands-on experience.

Aim of the workshop

Purpose of the workshop is to raise awareness about how a formal context for blended teaching and learning may be embedded in a strategic and sustainable manner. Moreover, by using a validated framework and a set of convenient tools, the participants will assess the maturity of blended education at their higher education institution. Thereupon, they are expected to draw up an action plan. This effort will allow their institutions to (further) progress towards a higher level of maturity in blended education.

The setup of the workshop

The workshop will start with a short presentation of the European Maturity model for Blended Education (EMBED). The pillars of the maturity model, next to its dimensions and indicators are elaborated. This introduction is followed by a showcase during which the maturity of blended education at Delft University of Technology is assessed. This will be demonstrated by various existing illustrative examples.

After the introduction, the participants will assess the maturity of their own higher education institution. This hands-on experience is conceived as a collaborative

activity in different online break-out rooms. Groups of two to three participants are triggered to exchange ideas, critical reflections and practices. These group processes will be supported by prepared items for discussion and questions prompted by the workshop facilitators (two in total). Each participant is expected to draw up an action plan for their own institution.
The workshop is concluded by collecting the insights and examples of the participants in each room. These are shared with the whole group, as well as their reflections on the maturity model and a series of recommendations for its future usage.

To summarize, by the end of this workshop the participants have:

- assessed the maturity of their higher education institution, using the EMBED framework;
- exchanged ideas with other participants and get inspired by novel approaches to become more mature in blended education;
- prepared an action plan for progressing their institution towards a higher level of maturity.

Background of EMBED
The EMBED framework is a validated reference model for developing and implementing blended teaching and learning. It is conceived as a multi-actor, multilevel model and focuses therefore on different issues: the design of blended courses and programs, organizational aspects such as support and training, institutional leadership, policies and strategies in support of continuous innovation, etc. The framework is developed by a strategic partnership of six frontrunner European universities in blended education. The EMBED project was co-funded by the Erasmus+ Programme of the European Union. More information can be found on: https://embed.eadtu.eu

AN INTRODUCTION TO SYSTEMATIC LITERATURE REVIEWS IN ENGINEERING EDUCATION

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***Keywords**: research methodology; systematic literature review*

INTRODUCTION

Whether you are new to engineering education research (EER) or an experienced researcher, knowing what prior work has been conducted in your topic of interest is essential. Literature reviews can not only inform your practice, but also help you identify gaps and new directions for further research. Literature reviews enable you to distil the knowledge necessary to participate fully and with authority in conversations on your topic. Developing a comprehensive review helps ensure you identify all past publications pertinent to your topic and provides a means for others to verify your work – a cornerstone principle of scientific research. In this workshop, you'll learn different typologies of literature reviews (e.g., narrative and systematic), how to identify the types, the advantages of and how to conduct a systematic one.

Launching into any new topic, you may feel overwhelmed. The available information may seem too vast and complex to synthesize and summarize. This is made more complex by EER being an emergent new field – one that draws from, and combines, expertise in multiple disciplines – which adds to the complexity of selecting and analysing literature. Using a structured approach to identify, select, and analyse the existing body of literature can help you build confidence by helping ensure consistency, quality, and reliability of your review.

This workshop illustrates and provides support for systematic literature reviews (SLR). A systematic review is seen as the gold standard in knowledge synthesis (Boland, Cherry, & Dickenson, 2013, in ten Ham-Baloyi & Jordan, 2015). The process of carrying out a systematic review is highly focussed on clearly defined research question(s) that a researcher is interested in. The research question is central to each stage within the process. Aligning each stage to the research question makes the research process explicit and reproducible (Pickering and Byrne, 2014). In the impossibility to keep pace of the ever-growing number of publications in engineering education research, systematic reviews are strong methodologies that can support you finding and understanding which questions have already been answered and which remain to be answered in your research field. Another advantage of this approach is that it helps to revisit the research question(s) to check for future developments and extending the synthesised evidence reliably.

Overall, the hosts of this workshop aim to help raise the quality, usefulness, and profile of EER by helping members of the EER community understand and build mastery of new research methods that have particular relevance for EER. The workshop steps participants through the rationale and processes behind SLRs and participation in it will help build a community of people to collaborate with and offer advice to one other in future endeavours. The three hosts, in fact, met at an engineering education conference and united with the purpose to master SLR techniques and have subsequently published reviews and provide workshops elsewhere. We hope to extend our network and promote this collaborative model for working.

Reasons to do a literature review

A few reasons to do a literature review are:

- To describe the state of the art and developments on a topic;
- To identify seminal works in your area;
- To discover how others researched your topic of interest, and identifying methods that could be relevant to your project;
- To identify gaps/opportunities for future research.

Such reviews can be narrative, using what could be considered convenience or purposeful sampling, or systematic, attempting for fair and equitable coverage of past research question and findings.

Although narrative reviews are the most common type of literature reviews, the analysis in the narrative reviews tends to be *ad hoc* and likely to support the author's intent – which may be to argue a certain stance. These reviews are often biased by literature's availability and reviewer's selection.

On the contrary, systematic literature reviews aim to reduce bias by designing and following a comprehensive plan and detailed search process based on well-defined research question(s) relating a particular topic.

Advantages of conducting systematic literature reviews to the Engineering Education Research community

Systematic literature reviews and narrative reviews may have some overlapping purposes and procedures, yet they constitute two distinctively different approaches to synthesizing the literature. SLR aims to minimize bias and error; the selection of appropriate studies follows objectively defined inclusion and exclusion criteria linked to the research question(s). It follows an explicit process that therefore can be replicated by others, and also at a point in future to re-map the boundaries of the literature in a progressive manner. SLR also is a Research Method; it implies methodical procedures matched to well defined research questions. SLR follows a study protocol and analysis plan – it is based on secondary observations, in which studies are the unit of analysis

Purpose

This workshop provides an introduction to various review types with a focus on SLR. It is tailored for new researchers in Engineering Education but is also of value to more experienced researchers who want to build skill in SLR and meta-analysis. The workshop will use a combination of short presentations and online hand-on activities.

Primary purposes of this workshop are to:

- introduce review typologies;
- describe SLR as a methodology for engineering education research, and highlight how it differs from other literature review methodologies;
- learn to define inclusion and exclusion criteria and use them to search databases;
- describe the steps involved in systematic reporting.

Structure

This 75-minutes workshop session will be organised in three blocks of short presentations and groupwork covering the following topics:

1. The types of lit reviews (including SLR)
2. Overview of the steps in SLR
3. How to report SLR

Participant engagement

Building on previous online workshops in EER organized and delivered by the authors, participants will be challenged to work collaboratively with other conference delegates in online breakout rooms. This format will not only enhance the community building aspect of the workshop, but also highlight the advantages/potentialities of working remotely in systematic literature reviews.

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DIVERSITY AND INCLUSION RESEARCH IN ENGINEERING EDUCATION: WHAT HAS CHANGED IN THE LAST 10 YEARS?

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Conference Key Areas: *diversity and inclusiveness*
Keywords: *engineering education research, gender, diversity, inclusion*

RATIONALE

"Diversity has an increasingly large part to play in the more globally oriented technical industry in bringing a sense of balance between several groups of personnel e.g. in gender, age, cultural background. These enterprises focus on better possibilities of recruiting, a long-term staff retention and a target group oriented product development for a better positioning at the market. Engineering education, however, works with a kind of mono-cultural recruiting, standardised learning offers for all students and a more general oriented product development and technical research." The former challenge for engineering education was put forward by Susanne Ihsen and Xiangyun Du in the Special Issue on Diversity concepts and experiences in Engineering Education of the European Journal of Engineering Education in 2009.

In our workshop we will jointly explore how the scholarship around diversity and inclusion in engineering education has evolved since and which additional research methodologies have been applied related to diversity and inclusion.

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The workshop has **four particular goals**:

1. introducing to each of the participants four different papers exemplary for methodologies or case studies for research on diversity and inclusion in engineering education.
2. community building: each participant is challenged to collaborate with new colleagues in the engineering education field
3. identifying opportunities of diversity and inclusion research for practice and for new research
4. exploring the (dis)advantages of joint paper-reading

PARTICIPANT ENGAGEMENT

The workshop is built on the successful workshops' formats that the SEFI Engineering Education Research and the Gender and Diversity Special Interest Groups have been running at the previous conferences. By joint paper reading and discussing in small groups using a jig-saw format, participants will explore the evolution of diversity and inclusion engineering education research in the last 10 years. Participants will be challenged to work in diverse groups with people they have not yet beforehand to enhance the community building aspect of the workshop. A plenary closing discussion will summarize good practices and formulate priorities for the next decade.

TAKEAWAY

The attendees will have gained insight in the evolution of the research in diversity and inclusion in the last 10 years. On top of detailed knowledge of four recent publications they obtain a list of further literature. Participant conclusions will be made available online after the session on the SEFI SIG websites.

BEST PRACTICES FOR REVIEWING MANUSCRIPTS IN ENGINEERING EDUCATION RESEARCH

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ABSTRACT

In this session, participants will consider best practices and generate practical advice for reviewing manuscripts in the field of engineering education research. Improving one's skills to review effectively is a wise investment. Reviewers can stay in tune with the field and acquire insights to improve their own writing. Understanding the editorial process from the inside is also helpful when taking one's own manuscript from submission to successful publication.

Workshop facilitators are a team of editors of four leading journals:

- European Journal of Engineering Education (SEFI)
- IEEE Transactions on Education
- Journal of Engineering Education (ASEE)
- Australasian Journal of Engineering Education (AAEE)

We welcome both experienced and new reviewers, especially doctoral students in engineering education research.

Participants will be able to:

- Explain different quality criteria for scholarship in engineering education, and how to apply them
- Highlight particular aspects of a manuscript that a reviewer should consider

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- Discuss how reviews can support editors in making fair decisions and authors in improving their manuscripts
- Consider how reviewers can spend their own time wisely

Introductions

- Brief introductions: participants and session leaders. [5 minutes]
- The journals: aims and scope, review criteria and review process. [15 minutes]

Group activity

- Make a poster in groups of four: “Advice for reviewers”. [30 minutes]
- Vernissage (hanging the posters).

Synthesis

- Plenary discussion of results. Editors’ picks. Collected wisdom and conclusions. [25 minutes]

Participants can sign up for receiving documentation from session, and volunteer as reviewers for the journals.

HOW TO STIMULATE COLLABORATION AND PERFORMANCE OF HIGHLY DIVERSE STUDENT TEAMS IN ENGINEERING EDUCATION?

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Due to technical changes and globalized markets, work is increasingly organized in teams consisting of people with different disciplinary and cultural backgrounds. Diversity in teams, especially deep-level diversity (attitudinal diversity, such as variations in values, attitudes, personality etc. (Harrison, Price, & Bell, 1998)), might stimulate innovation, because different perspectives and expertise can be used to solve problems. Diversity, however, may also lead to miscommunication and conflicts between team members (van Veelen & Ufkes, 2019). In engineering education, new educational formats such as challenge-based learning result in educational designs in which students with various backgrounds and expertise are required to collaborate together on projects and assignments (Kohn Rådberg, Lundqvist, Malmqvist, & Hagvall Svensson, 2020). But what is the best way to compose these teams and to support these teams in order to maximize the potential of these diverse teams and minimize possible negative effects?
In this workshop we present the materials and outcomes of a deep-level diversity intervention which was tested among 1100 engineering students from different disciplines and culture while they participated in a challenge-based international project week. During the project week, students worked in teams on different company assignments. On the first day, half of the student teams participated in the intervention. The intervention was designed to increase awareness of each other's professional identity (who are you as a professional?) in order to lower inter-group bias and stimulate the development of a team identity (Van Knippenberg, De Dreu, & Homan, 2004). They received feedback on their professional identity (competencies, values, interests and personality) and were challenged to design a team plan while taking into account each other's unique talents. We compared the project results, quality of collaboration, and feeling of inclusiveness of these teams that participated in the intervention with the student teams that did not participate.
We will start the workshop with introducing the concept of professional identity and how we conceptualise this in our project Bridge the gap! (Endedijk, van Veelen, & Möwes, 2017) and giving the participants the opportunity to do a short self-test to find out about their own professional identity. We will show the materials and set-up of the intervention, followed by an online voting to ask the participants to predict the outcomes of our study. This will provide insights in our own pre-conceptions of benefits and costs of diversity in teamwork in engineering education. After that, the outcomes of our intervention study will be shared via infographics. We will show how diversity (objective and perceived) in teams in terms of field of study, experience, national background and gender affected the quality of collaboration, performance and feelings of belonging and to what extent the intervention helped to counteract negative effects and further stimulate positive effects. The participants are invited to engage in small groups in a quick design of a similar intervention for their own

courses that require collaboration in diverse teams. The workshop will end with lessons learned: what to do and what to avoid when designing projects for teams with members with a diverse background.

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ABSTRACT WORKSHOP ETHICAL REFLECTION FOR ENGINEERING CONFERENCE

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Keywords: *Tools for Ethical Reflection in Engineering and Science Programs in Higher Education*

Reflection on societal and ethical aspects of technology is not yet commonly included in higher education programs. Most teachers are not sufficiently trained in ethical reflection and find it rather difficult to discuss ethical questions involving their own discipline with their students. However, nowadays ethical reflection on the impact and meaning of technological choices, makes up a necessary component of the research, design and development process. As future professionals (researchers included) our present students are expected to link options for technological innovations to the additional societal and ethical effects. Therefore, in this workshop the pertinent question about how ethical reflection can be made valuable and suitable for engineering programs, will be addressed

Ethical reflection on the impact of technology can take different forms, such as academic, societal -ethical and personal-ethical reflection. Academic reflection puts emphasizes on knowledge, theoretical frameworks and foundations (such as philosophy of technology); societal-ethical reflection deals with ethical questions in professional practices (for example about social implications of technical innovations in the own disciplines and about the consequences for society) whereas personal-ethical reflection stresses on one's own position towards one's profession (e.g. professional responsibility and professional identity).

At present, professional education programs tend to include personal-ethical reflection emphasizing on professional identity development (Trede, Macklin & Bridges, 2012) and on reflection on personal development from student to reflective practitioner during their studies (Mittendorff, 2014; Kember at all, 2008). Academic and societal- ethical reflection however, do not yet appear to be elementary parts of the curricula of (applied) engineering and science programs.

This lack is quite remarkable given the current request for ethical models from outside the educational context. Instruments and methods providing engineers and other professionals with most required tools for ethical reflection have been developed for professional practices, organizations and platforms. As such in The Netherlands, ECP (Platform voor de InformatieSamenleving) and philosopher Peter-Paul Verbeek recently published a joint edition of 'Ethical Accompaniment Approach' in which they explain a specific method to apply the thought of ethical accompaniment in everyday practice (Tijink & Verbeek, 2019). Steven Dorrestijn developed the Product Impact Tool, a model covering a repertoire of effects of technology ordered according to four different modes of interaction. Each mode is set

up with an interdisciplinary collection of relevant examples and useful concepts (see www.productimpacttool.org). By applying the tool in assessments and workshops for research projects about new technology, it evokes discussion and reflection about the impact of the (to be) designed product as well as about ethical concerns (Dorrestijn, 2017, in press). Finally, for a Space53 research project on new applications for drones Egbert Siebrand & Steven Dorrestijn designed an Ethical Readiness Tool. This tool can be complementary to a technical readiness level check and will be used to learn which ethical objections could obstruct social acceptance of a new technology (https://www.space53.eu/evenementen/35/workshop-drone-acceptatie/)

As the importance of the impact and ethics of technology in everyday practice of professional disciplines will only increase, we facilitate a dialogue in mixed groups of participants. This dialogue will be focused on three key questions:

1. Which reflective competences (attitude, skills and knowledge) on the impact of technology do our students need to develop being a critical professional and/or researcher in a way that is “practical” and fitting for academic and higher vocational education at engineering and science departments?
2. What (kind of) ethical reflection education is already being done? And, what should additionally be offered to engineering and science students at (applied) universities.
3. Which tools will be of good use and/or should be developed?

In the first part of the proposed workshop (30 min) the participants will exchange their thoughts and experiences in small groups. Starting point for these questions will be to bring up what parts ethical reflection are already been taken care of. And, to evaluate this current offered ethical reflection education. (question 2). Aim is to end with a generic outcome about vision and aim of reflective competences on the impact and ethics of technology (question 1).
In the second part (30 min) the participants will examine some recently developed methods and instruments and evaluate their experiences with them (question 3). Which approaches are qualified for ethical reflection in higher education? Which learning elements are important? And, what additional tools are specifically needed for proper reflection on the ethics and impact of technology in their own particular educational practices?
After the workshop (60 min) the participants will leave with ideas and tools about ethical refection on the impact and ethics of technology in higher education

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STIMULATING REFLECTIVE SKILLS AMONG ENGINEERING (AND SCIENCE) STUDENTS – A CASE OF VISION, CURRICULUM, GUIDANCE AND TEACHER PROFESSIONALIZATION

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The contemporary knowledge society of the 21st century requires students, among other things, to have the ability to critically react to fast knowledge developments and to think analytically and reflectively (Walma-Van der Molen & Kirschner, 2017). Research into the disappearance of technical employees from the technical labor market also shows that it is important to guide students in their professional identity development, in which reflection of students is crucial. All in all, reflection is seen by several authors as an important competence for higher education students.

Various studies show that educational programs and teachers experience difficulty with the effective use of reflection in education. In addition, engineering and science programs indicate that the linguistic form in which reflection often takes place does not always seem to suit the technical target group, or that engineering and science students have more difficulty experiencing the meaningfulness of reflection. Two preliminary studies have examined how technical higher professional education programs have currently shaped student reflection in their curriculum and how students and lecturers experience this (see f.e. Woudt-Mittendorff & Pullen, 2019). The studies show results in recommendations at four different levels: a) Vision and goal setting, b) Curriculum/Programme, c) Guidance of reflection activities, and d) Teacher skills.

In the project ‘Strengthening reflection in technical higher education programs’, eight technical higher professional education programs of two Dutch higher education institutes are working on the improvement of reflection in their programs. With a project team they work on achieving a better vision and goals with regard to reflection within the programs (a), to concretize it at the programme level (b). Investments are also being made to improve reflection activities for students (c) and they pay attention to teaching skills (d). During two school years, steps are taken through various meetings with the teacher teams to give substance to the four levels mentioned.

The workshop is open to teachers and students. They will experience activities that are also undertaken within the aforementioned study programs. The workshop will consist of two rounds. Participants will first focus on the vision/ goal setting and programme level, and in the second round on the guidance level and teacher skills. Participants will learn about reflection and the importance of developing a vision on the topic and why the curriculum level is crucial. The literature shows that there is often a lack of clarity about the goals of reflection or that these goals are barely made explicit (Van Beveren, et al., 2018). Reflection can be used for different purposes or different "objects". The 'object' of reflection can be more or less specific,

and it can also relate to various things, for example to reflection on yourself, reflection on a process, a product, or even wider on society or your environment and the ethical side (Grossman, 2008). This workshop will provide insight into this and the participants will make the translation into their own educational practice. What are meaningful reflection goals for beta students? Is it mainly about professional development or do we want and to help beta students to grow in their personal awareness? And what does that mean for the use of reflection within the curriculum in years 1 to 4?

During round two, participants will participate in reflective activities that will address a) important design criteria for guiding students during reflection activities and b) the skills that are required by teachers. Literature shows that reflection is only effective if an individual is not merely reflecting by himself, but also relies on another (critical) person who thinks along, asks questions, gives feedback and helps reflect (Gabelica, Van den Bossche, Segers & Gijselaers, 2012 ; Van Seggelen-Damen, van Hezewijk, Helsdingen & Wopereis, 2017). This guidance on reflection is best achieved in a dialogue (Meijers & Mittendorff, 2017) and is therefore an important ingredient for a good learning environment for reflection. However, the results of the preliminary studies show that students in technical courses still often have to reflect individually and usally in the form of a reflection report. Students indicate that they do not find this mode of reflection useful, and would prefer to reflect in the form of a conversation (see f.e. Woudt-Mittendorff & Pullen, 2019). In addition to their needs to reflect in conversational form, students also indicate that they lack guidance while reflecting. Where teachers often give students an assignment to reflect, they usually do not train or instructive students how to reflect and do not guide them during reflection activities.

Teachers need more clarity with regard to the concept of reflection, but especially to acquire skills to properly guide and assess reflection. During this workshop, handles and/or tools will be provided to shape reflection discussions. Participants will leave with an analysis of their own educational practice, as teacher of student, and with recommendations for future improvement.

To perform both rounds as well as possible, we opt for a 80-minute workshop.

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PRACTICE-ORIENTED RESEARCH APPROACH IN ENGINEERING EDUCATION PROGRAMMES

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Background and rationale

Political ambitions to stimulate higher education to benefit societal needs has led to fundamental reforms in tertiary education worldwide. In Denmark, education of school and preschool teachers, nurses, welfare professionals and practical engineers has traditionally been undertaken by non-research based educational institutions outside the university sector. The educational reforms undertaken during the last 10-15 years have transformed these institutions into research-based University Colleges (UC) that provide bachelor degree programs within these professional domains. The UC's are supposed to engage in 'applied research' activities that benefit not only education, but are also of value for stakeholders in society in general [1].

The introduction of UC's in Denmark – as a supplement to the traditional universities in providing research – might be taken as a sign of academic drift [2] and the priority of university research and research based teaching by policy-makers.

The bachelor of engineering programmes (BEng) are taught at various UC's and universities in Denmark. Based on the needs of the business sector, the programmes have a research-oriented and a practice-oriented research approach. This secures that businesses will be able to hire engineers possessing practical as well as up-to-date qualifications.

We see that the practice-oriented research approach [3] is conducted in different ways. It is not clearly defined or explained how the approach is enacted and understood in the sector. In some cases, collaboration with companies is done in problem-based and project-based settings where the students learn through work on real life cases with engineering problems[1]. This is one way to conduct practice-oriented research and thereby ensure that the educators are updated in the technical part and use the frameworks of today that the students will be expected to use in

their future job (in the companies) [4] These differences make it difficult to compare different courses and educations.

The purpose for this workshop is to discuss how practice-oriented research approach could be defined and to share ideas and experiences about how it is incorporated into courses and education programmes at different higher educational institutions. Each way of incorporation will be discussed in relation to effect, strengths and challenges. The focus will be on bachelor of engineering programmes. The main target group for this workshop is all teachers and educational consultants who have an interest in the topic. But others are also welcome to participate as we would like to have a broad discussion.

Workshop session

Introduction (5 minutes) (zoom) link will be sent out to the participants

The authors will set the scene by introducing the questions for discussion and describe why this is relevant and which dilemmas they see. The program for the workshop session will be explained including what the participants are expected to do and learn from the workshop.

Hands-on session (25 minutes)(break out rooms zoom)

The next step will be a hands-on session. The workshop authors will facilitate the session. The authors will mix the participants randomly and create “break out rooms” in zoom for each group.

Each group will discuss the following two questions and write some notes from the discussions. The authors will hand out some keywords for each question to start the discussion

- How can practice-oriented research approaches in engineering education be defined?
- How are practice-oriented research approaches incorporated into courses/educational programmes?
    - Effects?
    - Strengths?
    - Challenges?

At the end of the session, the participants leave the break out rooms and return to the main room. Each group will give a very brief presentation of their findings. The other participants will be invited to comment on these findings and the facilitators will facilitate the process. At the end of the session, the facilitators will summarize the discussion.

Discussion and conclusion (10 minutes) zoom

In the last part of the session, the participants will discuss the result of the hands-on activity and reflect on the process including feedback on the session.

Expected outcomes/results

At the workshop, the participants will discuss various definitions and approaches, and the expected outcome from the workshop is a broader understanding of practice-oriented research approaches and their use.

The authors will collect the conclusions from the workshop session and these will be included in the final conference proceeding.

How is this work significant for Engineering Education

Having a common understanding about the definition of practice-oriented research can be significant in order to enhance engineering education in general. It offers a common language to educators to incorporate relevant research into education programmes and strengthen the ability of students to apply practice-oriented research into practical challenges.

Acknowledgement

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MAXIMIZING THE ENGAGEMENT FACTOR FOR ENGINEERING, SCIENTIFIC, OR TECHNICAL POSTERS: PURPOSE, EXCHANGE, AND UNIVERSAL/ACCESSIBLE

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Conference Key Areas: *Interdisciplinary education, Future engineering skills*
Keywords: *posters, design, accessibility, best practices*

ABSTRACT

Using the online format in a live and interactive manner, this workshop will address—and challenge-- the “academic poster” as an information exchange medium for engineering, scientific, and technical work. (We will use the live f2f format provided by the conference, crowd-sourced documents, and polling/word cloud tools in the moment for true interactions.)

The genre of "academic poster" has been long considered to have a “settled” format, firmly grounded in intellectual traditions. Its overall purpose is to highlight the researchers’ work and provide an opportunity for networking with other experts with similar backgrounds or interests. The purpose of this workshop is to re-examine this traditional format, break it apart, and find better ways to meet the differing audiences that will attend poster sessions (whether they are face to face or online events). Despite the plethora of “best practices” guidelines available online or via conference organizers [1], many of us have attended failed poster session events. Mike Morrison, an advocate for billboard-style or Poster 2.0 design, goes as far to say that “poster sessions are usually a dispiriting waste of time for all involved” [2]. Novice poster makers treat the medium as a stand-up, large-form version of lengthy research reports. Experienced poster presenters make similar mistakes. Ineffective visuals, text-heavy practices, and poor design is evident at every conference or gathering. Therefore, the workshop presenters intend to re-route the approach,

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assisting participants to think about this question: “What do you want the audience to do after viewing your poster?”

This highly interactive workshop invites participants into a deep dive that will pull apart the expected norms of the EST poster, challenging creators to entirely reconsider purpose, appeals to specific academic communities [3, 4], universal design/accessibility, design, and more. We will investigate two types of poster sessions: interactive/reciprocal/supported (with speakers present) and static/unsupported (with no speakers present) [1]. As well, due to the nature of a pandemic world, we will address the different ways that poster sessions can be hosted or used for online events.

Participants will learn how to help colleagues and interested experts come away from a poster with action items and collaborations in mind. Based in cognitive research [4-7], multimodal theory [4-7], and learner outcome pedagogies, participants will investigate poster creation by examining communicative context, communicative design, engineering identity, and engineering practice [7]. Additionally, issues of supplementary information dispersal (post-event) and accessibility for disabled attendees will be addressed [8, 9].

Specifically, workshop participants will:

1. analyze, in guided discussion, several poster designs, content, and delivery methods;
2. interact in synchronous “live” groups, assessing the features of poster design and content and tapping into the collective creative intelligence of participants;
3. creating rich descriptions of desired poster features and audience-engagement outcomes;
4. re-imagine and critically assess, in guided groups, on their own poster design and best practices checklist using these rich, curated principles for poster design using the customized sketchbook provided (which will also contain resources and prompt materials for take-aways).

It is desirable that attendees have a future/current/planned poster idea or draft on hand that they can share via guided online breakout room discussion. As well, a smartphone will allow participants to more easily contribute to our online information gathering that results from our discussions about how to re-imagine posters.

Participants will leave with a mature set of workshop materials available immediately online, including a customized sketchbook and sets of resources for poster best practices. Materials will also include the group-sourced outcomes that are generated during the event.

INTERDISCIPLINARY ENGINEERING EDUCATION, LINKING DIFFERENT DISCIPLINES BOTH INSIDE AND OUTSIDE ENGINEERING LINKING WITH SOCIETY

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How to use an assessment as learning (AAL) approach within authentic interdisciplinary learning environments

Solutions to complex societal, political and economic challenges increasingly are developed during interdisciplinary collaboration. This in turn entails curricula to prepare students for working in interdisciplinary projects. It requires students to broaden their perspective across disciplines and relate their own subject knowledge to knowledge of other subject areas and develop their problem solving skills. In our experience, one of the challenges with interdisciplinary project work is how to assess the work of students. The foci, scope and range of authentic assignments make it hard to construct generic criteria against which students can be assessed. Additionally, using generic criteria implies a risk that assessment takes place on a shallow level and does not engage students to take responsibility for their own learning. The challenge is to change the mere focus on summative assessment towards forms of formative assessment, in order to help students gain insight in their learning process and to support them in this process.

A possible solution for these challenges is implementing *assessment as learning*, where the focus is on student learning and development, and where assessment is used as a learning instrument. It emphasizes learner agency which entails that students have control over what and how they learn within the boundaries of the authentic learning environment. Continuous formative constructive feedback is a key element to help improve and maintain focus on learning.
When a summative verdict is necessary, through using an assessment as learning approach, at the end, the result of this summative judgment should not be a surprise for students anymore, since they already have received frequent formative feedback, feedup and feedforward and adjusted their learning accordingly.

Currently, we are developing an assessment as learning approach in the Smart Solution Semester of Saxion University of Applied Sciences, where third-year students from three or more (engineering) disciplines work together in project teams on large (25 ECTS) projects, provided by research groups and the business community. In this semester, students are assessed on their learning outcomes by using a portfolio assessment. The assessment revolves around three domains: usage of knowledge of own and other disciplines, professional skills, and developing research competences and an inquiry mindset. Additionally, a pilot is currently in progress in which students set their own learning goals and monitor these goals during the course of the Semester. Students frequently seek and receive formative feedback during the semester through feedback from peers, tutors, and experts.

Workshop design
In this workshop, we will provide recent insights from research on assessment as learning, and provide several illustrative examples from our experiences in the semester. Additionally, participants will work on a case -either from their own practice to translate a more traditional assessment method to an assessment as learning approach.

Overarching learning goal: Participants understand the key features and strengths and weaknesses of an assessment as learning approach and relate these to the methods of assessment that are used in their own practice.

Introduction (15 min.)
Assessment as learning within the Smart Solutions Semester – our experience
We will explain briefly the key elements of 'assessment as learning' from literature and share our experience with the implementation of this approach within the context of the Smart Solutions Semester. For every key element we will provide examples from practice. The focus will be on different types of formative evaluation and the value of continues constructive feedback.

Assignment in small 'break out'groups (15 min.)

- Based on the previously shared key elements of an AAL approach participants analyze an example from their own practice where students work together in (multidisciplinary) groups. A framework for analysis is provided.
- On a Padlet they write down the strengths, weaknesses, opportunities and threats they see when using an AAL approach in their own practice.
- In small groups they will discuss the analysis. What similarities are there and what differences? Together with the moderator they will draw an overarching conclusion to whether this approach would be feasible for their context..

Evaluation assignment whole group (5 min.)
We will invite participants to share the overall conclusions of their subgroup. Conclusions will be discussed in relation to the key elements of AAL.

Evaluation (5 min.)
Short evaluation of the workshop
The main question in the evaluation will be: 'What will you do different now after this workshop?' In other words, what are new insights you have gained or what will you test/implement in your own practice?

SO I HEAR YOU ARE AN EXPERT ON ONLINE TEACHING NOW? SHARING THOUGHTS, EXPERIENCES, AND VISIONS ON ONLINE TEACHING FROM THE NEW GLOBAL ONLINE TEACHING COMMUNITY

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Conference Key Areas: *E-learning, blended learning, virtual reality*
Keywords: *Elearning, Virtual Reality, Open Education*

ABSTRACT

It is strange writing this abstract with the thought of the COVID-19 crisis having hopefully past and us returning to our normal academic lives for the SEFI2020 annual conference. But the crisis will eventually pass, and with its passing new opportunities will arise – some even from unexpected
impacts of the crisis itself. One such impact is that we now have a global online teaching community.
Almost every teacher in post-secondary education was thrust into the deep end with respect to online education at the beginning of the crisis. My biggest fear is that negative experiences and frustrations may emerge and set in people's minds, framing online as the kryptonite of effective education. However, there is hope. With virtually everyone having some experience with online teaching and learning, we are positioned to have a very informed and potentially effective dialogue about the future of online teaching in engineering education with a wide diversity of informed views. The SIG on Open and Online Education would like to facilitate this dialogue through a workshop to discuss online education and collect the thoughts, experiences, and visions of the SEFI community on the topic.
In this workshop, we will be breaking into smaller groups to discuss and reflect on our experiences with respect to different topics around online learning. We hope to engage online education veterans as well as those that may have only been recently exposed to the world of online. Below is a preliminary list of topics, but these are subject to change as individual people are contacted to lead the discussion of the small group. For each of the topics, three basic questions will be examined:
1. What have your experiences over the past half year taught you with respect to the subgroup topic?
2. What do you think could/should be done in the future to further the potential of thesubgroup topic in the future?

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3. What do you see as a possible role for SEFI in furthering the subgroup topic?
Topics being considered for the subgroups in the workshop at the moment include:
· Assessment in an online world
· From hands-on project learning to virtual project learning
· Engagement and interaction in an online environment
· Best practices and tools

TOOLBOX FOR INTERNATIONALISATION: A DIGITAL BOX FULL OF RELEVANT INSIGHTS, HANDS-ON SOLUTIONS AND USEFIL TIPS

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Topics: *Diversity and inclusiveness, Internationalisation, joint programs*
Keywords: *international classroom, toolbox, teaching, practical solutions*

This workshop introduces a toolbox for internationalisation of education, aimed at university lecturers in for example an international classroom teaching situation. This topic is important because more and more programmes are taught in English with a mix of students with a diverse background. This diversity in the international classroom includes national and ethnic backgrounds, gender, age, study discipline, beliefs and religions, spiritual and sexual orientations, life experiences, (dis)ability, etc. To maximise the benefits of this mix and to offer each student the same opportunity for study success is not an easy task. The purpose of the workshop is to discuss issues in the international classroom, share experiences and give each other tips using the toolbox for internationalisation.

The toolbox is designed for lecturers to support them in their development towards a true international classroom. The toolbox is structured around definitions of the internationalisation issues addressed, practical solutions for the lecturers and references for further reading including background literature. The following topics are dealt with: the importance of internationalisation, course development, teacher competences, student preparation, and diversity in the international classroom.

Staff and lecturers from three technical universities in the Netherlands (the University of Twente, Eindhoven University of Technology and Wageningen University & Research) developed the toolbox, funded by the Centre of Engineering Education (CEE) from the Dutch technical universities organisation. The toolbox development was started after an inventory was made amongst programme directors at these institutes to find out what kind of support they need for the development and implementation of the international classroom concept and an international curriculum. The results showed that they wanted to receive training and have an online toolbox with practical tips and a useful literature.

The workshop offers the opportunity to explore the toolbox and to discuss with colleagues various issues/ cases concerning the international classroom. After a short plenary introduction, we will split up in sub-groups, where we will discuss a selected case from the international classroom and explore it from several perspectives, using the CEE Toolbox for Internationalisation. Several cases will be available, from which participants can choose the case of their interest. The practice-based cases address issues like assessment, group work, and student integration. It is also possible to bring in your own situation.

Programme:

0-15 mn Plenary introduction with awareness exercise

15-45 mn Subgroups – Zoom break-out rooms (choose one)

A. <u>How can we internationalise our programmes?</u>
Research shows that to prepare students for global citizenship and the global workforce, cross-cultural interactions are beneficial to students. In order for students to learn from cross-cultural interactions these interactions have to be organised, because learning is not a natural consequence of having students from diverse backgrounds in the classroom.

In this subgroup, you will explore how you can organise learning from cross-cultural interactions in your programmes and curriculum, using the Toolbox.

B. <u>Teaching competences for teaching in an international classroom</u>
Intercultural competence is not automatically developed just by teaching in an international environment. Intercultural competence should be seen as a process, that involves awareness, self-reflection, reflexivity and the development of knowledge and comprehension about cultural differences.

In this subgroup, you will explore the competences that are needed for teaching in an international context, as well as the process to acquire these competences, making use of the resources in the Toolbox.

C. <u>Preparing students for learning in an international classroom</u>
Preparing students for learning in an international classroom involves different aspects, from setting the general context of cultural awareness, developing intercultural competences, to raising interaction between students.

In this subgroup, you will explore the different aspects of preparing students for learning in an international classroom, making use of the Toolbox.

D. Diversity: going beyond cultural differences
Diversity in the classroom goes beyond what is visible like gender, age, ethnic background, dress-code, etc. It also includes various cultural differences, interdisciplinarity, diverse socio-economic backgrounds, sex-orientation (for ex. LGBT), physical disabilities, learning styles, specific talents, etc.

In this subgroup, you will explore how to develop awareness and respect for diversity and how to move towards inclusion in your classroom, using the Toolbox.

45-60 mn Harvest of the subgroups and wrap-up

The target group for the workshop are university lecturers and staff involved in designing and teaching international classrooms.

SUPPORTING SECONDARY STEM EDUCATION AND ATTRACTING STUDENTS TO SCIENCE AND TECHNOLOGY

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Is your science or engineering field known to secondary school teachers and students? We will show you some of our efforts to support secondary STEM teachers and students in their regular curriculum and to enrich their experience using up-to-date science and technology experiments. In a 5-minute overview we will present the main features our model for school – university cooperation in which school teachers with strong science and engineering backgrounds develop program content for high school students and for professional development of teacher colleagues in close cooperation with university experts. Content is focused on new topics in the school STEM curricula and linked to university R&D. Lesson materials are developed together with response groups of teachers and extensively tested in their classrooms and revised. This joint curriculum development turns out to be the best professional development for teaching the new curriculum topics. What are the benefits for the different stakeholders? How do we optimize them? What are our strengths and what are our difficulties?

Our outreach goals are: a) to support curriculum and professional development on new curriculum topics which can be linked to prominent university research areas, and b) to maintain strong connections between teachers and schools and the university.

After the introduction we will introduce three topics in short 7-minute video presentations which are each followed by 3 minutes of questions by the online workshop participants.

1) Lab-on-a-chip is one of the research topics studied intensively at University of Twente. Starting 10 years ago, STEM lesson series were developed by teachers and university researchers, tested in schools and revised and now routinely used in schools. The sophisticated practical kit provides equipment of professional quality with delicate glass devices. Students are enabled to become experienced with the microfluidic equipment, and to study fluid physics, electrochemistry and biological experiments. The number of high schools working with the kits is limited due to costs.

A new approach was found in easy-to-use techniques to facilitate students to design and produce their own Lab-on-a-chip devices. The basic version may be produced in matter of minutes, also by young children. Upper level high school students use the

more advanced designs, illustrating all principles of microfluidics. However, they can also design and produce their own Lab-on-a chip devices. Deposition of gold nanoparticles, using a quick reaction at room temperature, serves to characterize the flow patterns in the chips. This helps students to evaluate their design, and facilitates learning microfluidic concepts. In the online presentation, we demonstrate the approach and show images of classrooms where students apply these techniques and produce and test LoC devices with dyes or the gold nanoparticle reaction. In the break-out group after the presentations hands-on practicals are demonstrated and discussed in more detail, focusing on learning outcomes and possibilities for wider implementation in the countries and educational systems of workshop participants.

2) Quantum Suitcase Experiments were developed to support the teaching of quantum physics in secondary schools and add an experimental component to it. The experiments are mounted in suitcases which can be borrowed by teachers to perform the experiments in the classroom. Experiments include the hydrogen spectrum, the photo-electric effect, wave-particle duality by means of a double slit experiment with single photons, and a tunneling experiment in which laser light experiences total internal reflection in a prism but some light can tunnel through a wedge of the reflecting surface with a second prism. For the latter two experiments quite a bit of educational engineering was needed to optimize the pedagogy of the experiments and the supporting lesson materials. This was done in collaboration with 5 schools and teachers and 180 students. For our current optimized version retention interviews show that a majority of the students even after 4 and 9 months remember de relevant details and main principles. In the online video presentation, we demonstrate the double slit experiment with single photons and learning results measured 4 months and 9 months after the demonstration. In the break-out group we would like to focus discussion (using online tools) on the role of secondary teachers in UTwente outreach, and on an exchange of ideas about to what extent our methodology for outreach is feasible for other countries and education systems.

3) Nanochemistry: Two modules based on cutting-edge chemistry research were developed. The first module is about early cancer diagnosis, and the second module is about using renewable resources as building blocks for chemicals. These modules were developed by a team of teachers and university researchers and are currently used in chemistry lessons in secondary education. The basis of these learning materials was research that takes place at the Molecular NanoFabrication department at the University of Twente.

In this workshop we will present the design of the module "Early Cancer Diagnosis." Research on the detection of circulating tumor DNA was transformed into learning materials in which students learn about chemical bonding and some cancer chemistry. In the break-out group after the presentation, we moderate a discussion with participants on the possibilities and challenges when designing learning materials based on recent scientific research. Furthermore, we can give the participants a guided tour of our (Dutch language) interactive online lessons on early cancer diagnosis.

After the presentations we will form 3 break-out groups, one for each of the three topics with the questions indicated above for about 15 minutes.

After the break-out sessions we will come together again for 10 minutes and (using online tools) will summarize the strong points and potential weak points of the UTwente outreach approach.

REPORTS

WORKSHOPS

DOCTORAL SYMPOSIUM

SEFI FRANCESCO MAFFIOLI AWARD

THE FUTURE OF CONTINUING ENGINEERING EDUCATION IN THE ERA OF DIGITALIZATION AND PERSONALIZATION

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Conference Key Areas: Future engineering *skills and talent management, Engineering curriculum design, challenge-based education, maker projects, use of professional tools.*
Keywords: *continuing engineering education, lifelong learning, upskill and reskill, professional development*

ABSTRACT

The pace of introduction of new technology and thus continuous change in skill needs at workplaces, especially for the engineers, has increased. While digitization induced changes in manufacturing, construction and supply chain sectors may not be felt the same in every sector, this will be hard to escape. Both young and experienced engineers will experience the change, and the need to continuously assess and close the skills gap will arise. How will we, the continuing engineering educators and administrators will respond to it?
Prepared for engineering educators and administrators, this SEFI workshop has shed light on the future of continuing engineering education as we go through exponentially shortened time frames of technological revolution and in very recent time, in an unprecedented COVID-19 pandemic.

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1 INTRODUCTION

1.1 Background

As rapid technological advances continue to transform the world of work, education systems play a critical role in preparing the global workforce of the future. Today, with the emergence of unpredictable global risks, such as the COVID-19 crisis, the educational models of higher education and continuing education institutions must be flexibly adapted to equip workers with the necessary tools to mitigate skills mismatches and identify viable models of quality education. Education in the Fourth Industrial Revolution can be modeled with the following four skills and four learning characteristics of high-quality learning as Education 4.0 Framework [1], as shown in Table 1.

TABLE 1. Skills and learning characteristics of high-quality learning as Education 4.0 Framework [1]

Skills	1. Global citizenship skills 2. Innovation and creativity skills 3. Technology skills 4. Interpersonal skills
Learning Characteristics	1. Personalized and self-paced learning 2. Accessible and inclusive learning 3. Collaborative learning 4. Student-driven learning

The 21st century featured irreversible transformations that generated substantial changes in workforce development. International organizations including the Organization for Economic Co-operation and Development (OECD), and World Economic Forum (WEF), in their pre-2020 reports, presented the situation as a global challenge: “meeting new demands requires focusing on the nature of future work and on the skills of the workforce to perform adequately those works” [2,3].

1.2 Workshop Focus

Traditionally, professional engineers and technologists have practiced a structured path for advancement in career, thus continuous professional development for those engineers has followed structured curriculum and pathway. However, during Industry 4.0, an era of digitalization – artificial intelligence, robotic process automation, data analytics, and blockchain --, does it look the same? Or, during the yet to arrive Industry 5.0, which is predicted to be the era of personalization and focus on humans and machine cooperation, how will the path of continuous professional development of the professional engineer look like? Will the engineers ever stop learning? Will they continuously have to reskill to cope with the ever-changing technology-based workplace or simply upskill to move forward?

As we are experiencing the consequences of the COVID-19 pandemic, we are asking ourselves, what knowledge, and skills that the industry will need in the post-pandemic world? Will it radically change from pre-pandemic need? Will the industry change so rapidly over the next few years that the engineers will need to reskill and upskill themselves continuously? Will academia be able to prepare the students for a life of continuous learning?

At the 2019 Annual SEFI Conference, the Continuing Engineering Education and Lifelong Learning Special Interest Group started preliminary conversation, followed by a hybrid meeting with both face-to-face and online attendees. The group wanted to evaluate the current and future work scenario, the change required in engineering education to accommodate the work scenario and whether there would learning communities needed to foster such changes.

However, there was no pandemic at that time. After the pandemic started, the situation changed and through virtual connection, the workshop was conducted at SEFI 2020.

2 METHODOLOGY

2.1 Before the Workshop

Before the workshop, the participants were requested to read several web-based, freely available articles and international reports focused on the future of work and learning, as cited in the References [4-8].

The presenters also did a thorough investigation of engineering jobs in the market. There was no dearth of jobs for blockchain engineers or robotic process automation quality assurance engineer. It was also evident that the advent in artificial intelligence created jobs such as machine learning engineers. The presenters decided to share this information with the workshop participants.

2.2 During the Workshop

This workshop aimed to gather practitioners in the field of lifelong learning in engineering to brainstorm several paths for closing the obvious skills gap, rapid curriculum development, and deployment via accessible formats, flexible learning modes and paths, assessment, learning outcome evaluation and recognition, accreditation, and personalization.

The workshop participants critically assessed:

- the skills that the industry will require from the engineers in entry level and later
- how the industry and academia collaboratively can develop continuing engineering education curriculum to address such needs, and

- how the industry and academia collaboratively can prepare the students for a lifetime of learning.

2020 – The year of Coronavirus COVID-19 posed more challenges to overcome: work from, remote teaching and learning, factory job elimination, rapid digitization in all sectors and new types of skillsets in jobs. Change had happened at faster rate than anyone had thought.

The triggers questions to invigorate the thought process of the participants are shown in in Figure 1.

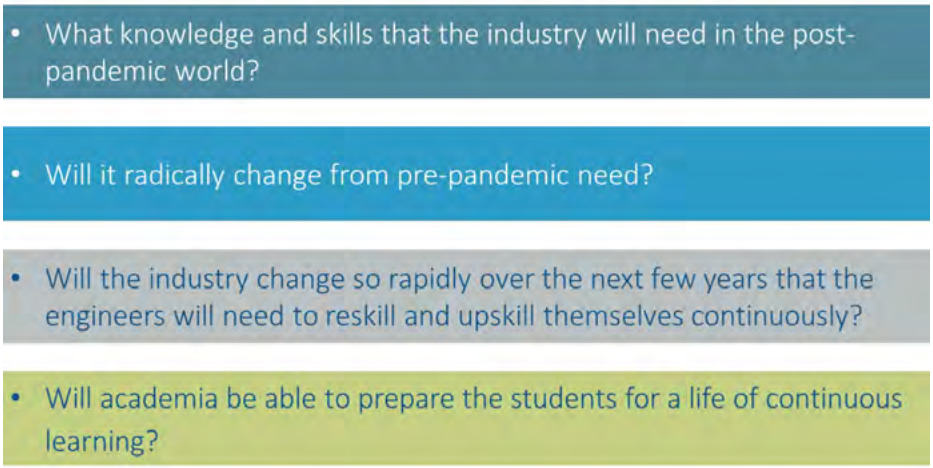

Figure 1. Trigger questions for the participants

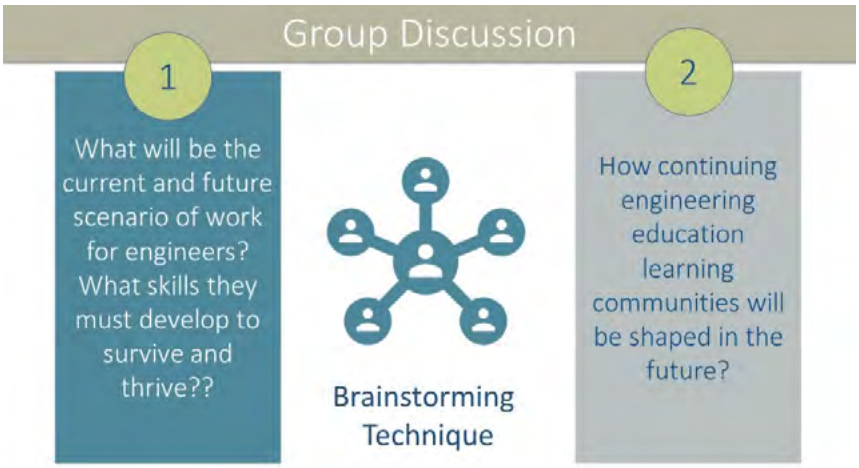

Figure 2. Group discussion and brainstorming at the breakout rooms

The 75-minute virtual workshop was divided into four sections:

1. Presentation on the current situation of work and learning and triggering questions, shown in Figure 1. [Main Virtual Room]

2. Brainstorming discussions in two groups (as shown in Figure 2) on the possibilities during Industry 4.0 Digitization and possibilities during Industry 5.0 Personalization [Breakout Virtual Rooms].
3. Presentations on the future of work and learning [Main Virtual Room]
4. A list of work to do by the participants, as the workshop outcomes were summarized. [Main Virtual Room]

3 RESULTS

At the end of the workshop, participants experienced the following learning outcomes:

- A thorough knowledge of the current and future scenario of work for engineers
- how engineering education will need to incorporate a lifetime of learning mindset
- a framework developed by the participants themselves on how continuing engineering education learning communities will shape in the future while remaining agile in nature.

By answering the questions shown in Figures 1 and 2, we got preliminary ideas on how to proceed:

- Reinforce continuous training and upskilling in newer technologies such as Artificial Intelligence and Machine Learning, Robotic Process Automation, Blockchain-Based Operations, Services and Products Design and Simulations in undergraduate, graduate, and professional engineering education curricula.
- Reinforce the role of the educator as facilitator of the students so that they continue to “learning to learn” for the future work.

From a brief review of the documents that were available to the participants before the workshop, and the comments that emerged in the group discussion and brainstorming session, some relevant aspects could be obtained that had the consensus of the participants. Regarding how to build skills at “*speed & scale*”, we understand the importance of:

- Relate the business goals directly with the skills that are planned to be built, considering the planning of the workforce as an ongoing process.
- Include everyone -employees and employers / students and teachers- to create a culture of learning.
- Continuously measure and evaluate the relationship between learning and digital transformation goals.
- Do not forget the formal training, to teach people How to Learn.

4 SUMMARY AND ACKNOWLEDGMENTS

The workshop participants agreed to highlight the following aspects as the most important related to the future of Continuing Education in Engineering:

With regard to Global Citizenship: raising awareness about the world in general and the active role that we must play in the global community;
With respect to collaborative learning: require the active collaboration and commitment of all colleagues and an approach that reflects the needs of future work; and
Finally, with respect to Innovation and Creativity Skills: include complex problem solving, analytical thinking, and ethical use of emerging technologies.

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MAXIMIZING THE ENGAGEMENT FACTOR FOR ENGINEERING, SCIENTIFIC, OR TECHNICAL POSTERS: PURPOSE, EXCHANGE, AND UNIVERSAL/ACCESSIBLE DESIGN

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Conference Key Areas: *Interdisciplinary education, Future engineering skills*
Keywords: *posters, design, accessibility, best practices*

ABSTRACT

Using the online format in a live and interactive manner, this workshop addressed—and challenged—the “academic poster” as an information exchange medium for engineering, scientific, and technical work. (We used the live f2f format provided by the conference, crowd-sourced documents, and polling/word cloud tools in the moment for true interactions.)

The genre of "academic poster" has been long considered to have a “settled” format, firmly grounded in intellectual traditions. Its overall purpose is to highlight the researchers’ work and provide an opportunity for networking with other experts with similar backgrounds or interests. The purpose of this workshop was to re-examine this traditional format, break it apart, and find better ways to meet the differing audiences that will attend poster sessions (whether they are face to face or online events). Despite the plethora of “best practices” guidelines available online or via conference organizers [1], many of us have attended failed poster session events. Mike Morrison, an advocate for billboard-style or Poster 2.0 design, goes as far to say that “poster sessions are usually a dispiriting waste of time for all involved” [2]. Novice poster makers treat the medium as a stand-up, large-form version of lengthy research reports. Experienced poster presenters make similar mistakes. Ineffective visuals, text-heavy practices, and poor design is evident at every conference or gathering. Therefore, the workshop presenters intended to re-route the approach,

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assisting participants to think about this question: “What do you want the audience to do after viewing your poster?”

This highly interactive workshop invited participants into a deep dive that pulled apart the expected norms of the EST poster, challenging creators to entirely reconsider purpose, appeals to specific academic communities [3, 4], universal design/accessibility, design, and more. We investigated two types of poster sessions: interactive/reciprocal/supported (with speakers present) and static/unsupported (with no speakers present) [1]. As well, due to the nature of a pandemic world, we addressed the different ways that poster sessions can be hosted or used for online events.

Participants learned how to help colleagues and interested experts come away from a poster with action items and collaborations in mind. Based in cognitive research [4-7], multimodal theory [4-7], and learner outcome pedagogies, participants investigated poster creation by examining communicative context, communicative design, engineering identity, and engineering practice [7]. Additionally, issues of supplementary information dispersal (post-event) and accessibility for disabled attendees was addressed [8, 9]. Specifically, workshop participants:

1. analyzed, in guided discussion, several poster designs, content, and delivery methods;
2. interacted in synchronous “live” groups, assessing the features of poster design and content and tapping into the collective creative intelligence of participants;
3. created rich descriptions of desired poster features and audience-engagement outcomes;
4. re-imagined and critically assessed, in guided groups, their own poster design and best practices checklist using these rich, curated principles for poster design.

It was desirable for attendees to have a future/current/planned poster idea or draft on hand that they could share via guided online breakout room discussion. As well, a smartphone allowed participants to more easily contribute to our online information gathering that results from our discussions about how to re-imagine posters. Participants left with a mature set of workshop materials available immediately online, including sets of resources for poster best practices. Materials also included the group-sourced outcomes that were generated during the event.

Slides, resources, and references can be retrieved from Workshop W322’s website: https://chec.engineering.cornell.edu/sefi-2020-workshop-materials/

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LESSONS LEARNED IN THE DOCTORAL SYMPOSIUM IN ENGINEERING EDUCATION RESEARCH AT SEFI 2020

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Keywords: Engineering Education Research, doctoral education, networking

ABSTRACT

The 4th Doctoral Symposium at SEFI 2020 attracted 21 doctoral students and 17 senior researchers. For the first time, it was organised as a fully online event. In preparation, the doctoral students wrote extended abstracts to introduce themselves and their PhD projects, while the seniors provided reading tips and advice. The intense, full-day program was based on group discussions and interactive plenary sessions. The Doctoral Symposium was concluded by a session in which each participant presented their take-home message. This paper outlines how the Doctoral Symposium was organised and summarizes some of the documentation.

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1 INTRODUCTION

1.1 The SEFI Doctoral Symposium

With the exception of a few larger research centres, doctoral education in engineering education research (EER) is often organised in relatively small scale at each institution – this is not least true in Europe. Therefore, it is important for PhD students to network outside their own research environment, in order to enhance the doctoral student experience, support their development as researchers, and increase their understanding of the EER field as a whole. Networks, both regional and international, can also be seen as an act of creating and maintaining connections to strengthen the research field as a whole [1, 2].
The European Society for Engineering Education (SEFI) recognises the EER field and its importance for furthering engineering education. Through the Doctoral Symposium in Engineering Education Research, SEFI offers PhD students opportunities to share their work with peers and with senior researchers, to build their network, and exchange feedback. The purpose is that participants will:

- meet other students and supervisors to extend their network and view of the EER field,
- present and discuss their own work and the work of others,
- get perspectives from scholars outside their own institution,
- contribute to the conference and the SEFI EER community, and
- promote collaborative research and elaborate future research directions.

In three previous SEFI conferences, a Doctoral Symposium in Engineering Education Research (DS) has been held as full-day pre-conference events: before the SEFI Annual Conference 2016 in Tampere, 2018 in Copenhagen, and 2019 in Budapest. The purpose of this paper is to document and share some insights into the process and products from the DS 2020. In the following, we discuss recruitment of participants – both the doctoral students and experienced researchers, and explain the activity design. We present parts of the rich material that was created, in particular the advice from seniors and the individual reflections from all participants.

1.2 The First Online Symposium

This year, due to the Covid pandemic, the DS had to be arranged online, just like the SEFI2020 conference. Travel restrictions had been in place during the six months preceding the DS, and many had been working mainly from home. It had already become obvious that the lack of mobility and networking was a tough consequence for doctoral education. The scarcity of opportunities to build their own networks can be expected to be particularly serious for those who do not already have established connections that they can draw on. Therefore, the DS had a more important function this year than ever before.
The challenge when organising the event online is that, due to the nature of the event, the personal meeting is in focus. Therefore, it was particularly important not to lose the human, friendly, informal atmosphere. On the positive side, however, the

pandemic had also forced a quick uptake of online meeting formats, and the organisers never hesitated to redesign the event for fully remote participation.

1.3 Doctoral Student Participants

The doctoral students interested in participating were invited to send an extended abstract containing a *general introduction* (background and interest in EER), an *outline of their research* (elevator pitch, research interest, thesis title, supervisors, current work), *reflections* (questions, challenges, dilemmas, wishes and ambitions) and *preferences for networking* (at SEFI2020, and keeping in touch). The extended abstracts that were submitted showed that the doctoral students were in various stages in their PhD projects, representing a variety in topics from policy level to fine-grained class room studies. The 21 doctoral students that were accepted came from 10 countries: Australia, Belgium, Denmark, Germany, Hungary, New Zealand, the Netherlands, South Africa, Sweden, and the UK.

1.4 Senior Participants

A number of experienced researchers in the field – here called senior participants – were invited to provide the PhD students with feedback, coaching and guidance. It is important for the DS to have a high number of seniors. Just like in the previous symposia, the organisers wanted to keep the ratio of seniors to students very high, aiming at approximately 2 seniors per 3 doctoral students. The invitations were apparently very attractive, as almost every person agreed to volunteer their time. This year there were in total 17 seniors, including the organising team (the authors of this paper). They came from Argentina, Australia, Belgium, Denmark, Ireland, the Netherlands, Portugal, Sweden, Switzerland, the UK, and the US. Hence, the seniors were even slightly more geographically diverse as the doctoral students.

1.5 Groups

The core of the symposium was the group activities in which doctoral students and seniors worked together. Six groups were formed, each containing 3-4 doctoral students. The groups were composed taking into account a balance between diversity and similarity regarding years of experience, research interests – both topics and methods, university and country. To address the problems of participating from different time zones, some seniors were paired so that, at lunchtime, the two seniors from Australia were succeeded by US-based seniors. To guarantee continuity, each group had at least one European senior who participated the full day. Hence, groups contained 2 or 3 seniors. The groups were formed a week in advance, and a compilation of all extended abstracts were sent out. The instruction was to prepare by reading the abstracts of the doctoral students, at least the ones in their own group.

1.6 Event Outline

The event took place on Sunday September 20, as a pre-conference day before the SEFI 2020 Annual Conference. The program was designed to accommodate lively and deep discussions between PhD students and experienced researchers. The main parts of the program were group activities, interspersed with plenary activities:

09.00 – 09.10	Arriving in Zoom
09.10 – 09.20	Introduction & how the DS will work
09.20 – 10.00	2-minute introductions of seniors
	Break
10.15 – 12.15	First group session
	Lunch
13.00 – 13.45	Speed dating, 6 x 6 minutes
13.45 – 14.45	Second group session
	Break
15.00 – 16.00	Plenary report: Take-home messages

2 DOCUMENTED RESULTS

2.1 Reading Tips from Experienced Researchers

The senior participants were asked to submit some reading tips in advance, prompted by these questions:

- If a doctoral student wanted to read something by you, what would you recommend and why?
- Recommend one paper (not your own) for a starting PhD student?

These prompts resulted in a comprehensive collection of publications:

Lisa Benson chose a paper examining how students think about what it means to do engineering and be an engineer [3], pushing back on some narrow ways of thinking that are passed on from generation to generation of engineering students. She also recommended a "*readable paper that explains knowledge transfer, an important and complex concept in education"* [4].

Jonte Bernhard offered a paper on learning in laboratories [5] which demonstrates how engineering education can be improved through design-based research, as well as a book chapter in which he compares engineering education research with engineering research [6]. Together with Caroline Baillie he has also written about quality in EER [7]. Finally, he recommended an editorial by Jennifer Case that demonstrates the importance of being critical and going beyond *fads and jargon* [8].

Maartje van den Bogaard mentioned her paper on student retention [9], which

"*introduces complexity theory into thinking about educational issues. It also shows the synergy from collaborating with researchers from different fields and contexts, who are driven to understand a shared problem"*. She also promoted a paper by Padilla as "*a game-changer in thinking about student success and with an exemplary research design for a qualitative study"* [10].

Shannon Chance recommended a paper discussing methods, and with findings of interviews with teachers who implemented PBL showing how they overcame challenges and maintained enthusiasm for a difficult change [11]. She also pointed to the classic paper by Case and Light [12], as it "*captures what was happening in EER at a specific point in time and reflects the socially constructed nature of our field"*. The same paper was also recommended by both Anne Gardner and Roger Hadgraft.

Kristina Edström invited the doctoral students to take a historical excursion [13], and reflect on the EER field [1, 14]. She also recommended them to subscribe to updates of the latest articles in the European Journal of Engineering Education [15-19]. Some of these were published just days before the DS [15, 16].

Cindy Finelli offered "*a quick introduction to my research on student resistance to active learning, and practical implications for educators"* [20]. Her other suggestion was a paper by Borrego, discussing difficulties for engineers learning educational research methods [21].

Anne Gardner picked a paper in the general higher education literature [22], rather than an engineering education specific publication.

Roger Hadgraft recommended a recent overview of future educational models together with Kolmos [23].

Anette Kolmos introduced a new publication with a longitudinal perspective on PBL [24] and mentioned her literature review with Chen [17].

Tinne De Laet chose a paper that "*reflects the kind of work I love to do – research that impacts actual education, staff, and students. We show the dashboards we have deployed at our university to support first-year students, and the research connected to it"* [25]. The topic of her other recommendation was self-regulated learning [26].

Greet Langie chose a recent systematic literature review on early career engineers [27], and a review related to achievement [28].

Rui Lima recommended a paper on PBL with a deep interaction of students and companies [29]. His other choice addresses conceptualization and reflection about active learning [30].

Wim Van Petegem picked an international cross-disciplinary study on how to network as PhD students while learning in the digital world [31]. His other choice was a book, *The Digital Scholar* [32].

Maria Isabel Pozzo recommended a paper about a very useful data collection technique in empirical research, namely the survey [33], and she also recommended the first chapters in the book *Formation of a Scientific Mind* [34].

Johannes Strobel chose a paper highlighting that "*problem solving is a lot more complex and nuanced than often taught in engineering"* [26]; Tinne De Laet also recommended this paper. His next choice investigates how empathy is conceptualized in the engineering context [35]. Finally, he picked an investigation of students' motivation to study engineering [36], as "*it is so rare we do longitudinal studies. This is a very good example of what such a study can contribute"*.

Roland Tormey pointed to a paper on the impact of gender on group work [37], featuring data in naturalistic settings and co-authored with a group of master students. His other choice is a useful paper on systematic reviews [38].

Esther Ventura-Medina offered a paper related to group work, on student teams' strategies in their first PBL experience [39]. Her other suggestion is an influential paper on research methods [40].

2.2 Advice from Experienced Researchers

In their advance input, seniors were also asked to give one general tip for a starting PhD student. Below, the tips are in random order and somewhat edited for space:

Lisa Benson: Figure out what direction you want to go with in your research and narrow this down to a research question, or questions. First: What are you passionate about - what

made you pursue a PhD in engineering education? Second: What are some of the greatest needs in our world right now – what needs your attention? The intersection of these two ideas is your sweet spot – this is the area that deserves your attention and that will carry you through all the trials and tribulations of completing a PhD.

Jonte Bernhard: Visit other research groups for shorter (or longer) periods. Even if your supervisor and research group are the Best in the World you always learn something by contact with other researchers. It broadens your views.

Maartje van den Bogaard: Writing is a form of processing information, of sharpening your understanding, of creating a source to work with when you are ready to write your dissertation. Start writings right away. It is between a craft and an art. It is something you can learn. Your writing doesn't have to be pretty, it needs to do the job of communicating your ideas. Start bare bones with short sentences. The rest will follow.

Shannon Chance: Find optimistic and supportive supervisors and mentors.

Kristina Edström: Read, read, read... Explore themes, people, journals. Follow references and read even more. Note what is convincing. Note what makes effective writing.

Cynthia Finelli: Be kind to yourself - tending to your own physical and mental well-being is at least as important as making progress in your research!

Anne Gardner: Apply project management skills to your PhD.

Roger Hadgraft: The clearer you can state your problem, the easier it is to answer. Limit your scope to a problem that can be investigated within the time available. Also make sure that the data you need can be collected without unreasonable difficulty.

Annette Kolmos: Work on your research question.

Tinne De Laet: Build a relationship of mutual understanding, trust, and openness with your supervisor. Be open about your aims, doubts, and things that make you happy.

Greet Langie: Take your time to read, to decide what interests you most and to design your research methodology.

Rui Lima: Find a research topic that really motivates you.

Wim Van Petegem: Three things are important: 1. Focus, 2. Focus, and 3. Focus!

Maria Isabel Pozzo: Set fixed time in your weekly agenda to devote to work on your thesis. If you wait to have free time to work on it, it will never come; it’s up to you to make it.

Johannes Strobel: Keep track and explore what puzzles you – these puzzlements are great building blocks for research questions and research careers. Read what others have written in the area of your puzzlement.

Roland Tormey: Develop the skill of writing for a diverse audience at the beginning. This makes your life (probably also the relationship with your supervisor) much easier.

Esther Ventura-Medina: Take ownership of your research work – take initiative and be involved :-)

2.3 Group Notes

The six groups wrote collaborative notes during their time together, in total 3 hours. A Google Document was prepared with space for each group. The downloaded version of the notes is 15 pages long in total, and it is outside the scope of this report to analyse this comprehensive material. However, the groups seem to have followed the suggestions in the instructions, as the notes contain generous amounts of:

- Interesting things that resonate with us
- Ideas and strengths that we have identified
- Problems, questions or issues we have identified
- Tips, things to do, read or think about

2.4 Take-home Messages

Each participant was asked to formulate a short nugget of wisdom as a take-home message from the DS. In the final plenary session, each participant had 1 minute to present their take-home message. The recommended length was 1-2 sentences or maximum 100 words; below some of the messages have been edited for space.

Lisa Benson: We are all feeling a bit disconnected, even those of us who are not lone wolves, so it is important to be intentional about connecting with others. Reach out to other grad students or recent graduates to discuss each others' research, read and review each others' papers and provide each other with resources. Create your own research group online, which isn't so strange at the moment since we are all working online.

Ljubov van Beek: Whatever you are going through - you are not alone. PhD is a self-development project.

Jonte Bernhard: I am glad that so many could participate today. It was the largest number of doctoral students since the start of the Doctoral Symposium. I hope the meeting inspired you and you have learned something. You can always learn something by extending your network and you get new perspectives from visiting other institutes, and communicating with people outside your own close circle. Never stop to keep your mind open!

Anders Melbye Boelt: Create and support the development of networks with other PhD students researching a similar topic.

Maartje van den Bogaard: Serendipity is key in all we do: without serendipity, none of us would be working in this field. I think we need to cherish the idea that research in and pathways towards EER are not linear and depend on things out of our control.

Anita Campbell: It is possible to form connections with new people online. It's so useful to get a glimpse of how others work and think.

Shannon Chance: Journal manuscripts that get rejected at first and then later published get higher citations than those accepted by the first journal [Ball, P. (2012). Rejection improves eventual impact of manuscripts. *Nature*.]

Kurt Coppens: Pay attention to understanding the context of papers (e.g. cultural difference), especially when dealing with feedback literature. Writing for yourself is a good way to crystallize information. Find a coding system when reading papers and after a while try to summarize the codes.

Tinne De Laet: Whatever you do, make sure you know <u>why</u>, and keep on believing in what you do. You are not alone!

Kristina Edström: John Ruskin wrote "*the highest reward for man's toil is not what he gets for it, but what he becomes by it"*. Therefore, think less about "getting" a PhD, and more about who you want to become by doing it. What skills do you want to develop, what do you want to learn about, what kind of work do you want to prepare yourself for, what kind of expert do you want to be seen as? There are so many things you can shape in your PhD project to accommodate the learning that you desire.

Sina Enteshari: Getting to listen to other students struggles and hearing supervisor advice on how the research should be was superb. The discussion in our group was always evolving, and we covered different concepts. As an engineer, I found it interesting that for success in social science, you have to be a Friendly Cultural Stranger and keep asking questions from everyone in the faculty.

Cynthia Finelli: Be kind to yourself - tending to your own physical and mental well being is at least as important as making progress in your research! When planning where to publish your results, find the right journal. It isn't always about impact factor. Who is your intended audience? What you want them to take away from your writing? There are many related journals where you could publish, find one that FITS your goals.

Anne Gardner: Wherever we are on the researcher development trajectory, there are challenges dealing with what can look like interesting opportunities – it is always a good idea to think at least a little before saying yes – does this exciting looking opportunity align with my overall values/purpose?

Marta Gavioli: Educational Design Based Research goes from theory to practice to theory again, we are quite free in the methods to use as long as we can defend them

Roger Hadgraft: Focus! Get very clear about what issue you are trying to investigate. This will almost certainly mean you need to narrow your focus as time goes on because most studies start too broad at the beginning. This will require constant refinement of your research question.

Jolan Hanssens: Roger Hadgraft said: "*Education is not a stationary process. There is never a final answer. A group of people today will think differently than a group of people 10 years from now. Education is in that sense much more complex than, say, physics*." This highlights the value of different viewpoints. This is trivial to acknowledge but harder to really understand. The prevailing paradigm today might become irrelevant tomorrow after all. It is important to always keep an open mind.

Melanie Herzig: One of the most important things is to be sure about what you really want to measure in your study. Only then you can find the exact wording for your research question.

Ferdinand Kieckhäfer: Always state and motivate the choices I make (sometimes subconsciously) while researching.

Anette Kolmos: Always great to hear about the PhD students research projects. The process is very similar and the problems the same.

Nárcisz Kulcsár: The biggest problem in mathematics education is that the connections between mathematics and real life are not taught clearly. Knowing that something is useful enhances inner motivation.

Greet Langie: Each PhD student has different hurdles. Maybe you don't enjoy it for the moment, but at the end of your journey you will discover that the hurdles helped you discover new horizons. Enjoy the hurdles! Do not be afraid of walking new methodological ground, as long as you can defend it and provide justification for your work, all things were once new.

Mariana Leandro Cruz: As PhD students, we should be in contact with researchers (different from our supervisors) who see our projects in different perspectives. This gives us new insights that can complement our researcher.

Rui Lima: In the beginning, read and talk as most as you can about engineering education and EER topics that you will be struggling with. Don't be afraid of failing during the research

process, but learn with it. Once I heard in an ironic way that we do not finish a PhD, we quit it. And this idea was helpful for some of my PhD researchers to close and finish their work.

Ellen Lynch: We all struggle - but it is by struggling that we learn something.

Daphne Miedema: Work with researchers in different disciplines to find new perspectives.

Xin Ming: PhD research is about careful work in a well-defined area; To research is to find connection points among methods, theories, questions, observations and so on; To report about methodology is to convince others why your method is the right one for your question and give enough description about how it is applied; Having contacts with real people, both peers and seniors, is precious, especially in such a time when we meet through screens.

Ashlee Pearson: Imposter syndrome can creep in and make you doubt yourself and the validity of your research and results. Have faith in the processes outlined by the literature and those who have walked before you. If you're following a known and trusted process, you're going to be going ok, it's just the self doubt creeping in.

Wim van Petegem: Three things are important for a PhD researcher: 1. Focus (on the topic), 2. Focus (on the process), 3. Focus (on the life beyond). To become a good author, become a good reviewer. Build your own network – it is a transversal competence.

Maria Isabel Pozzo: Even in a forced online edition of the symposium there is a variety of activities that can be carried out to exchange and to learn from each other.

Iresha Ranaraja: PhD is a journey with lots of ups and downs and added to that we have so much uncertainty around. Connecting with peers and getting constructive feedback from seniors from a supportive community like this gets you inspired and motivated to do better.

Elien Sijmkens: Make your research question very clear and specific, but also to identify the different elements of the question and decide in which elements you want to dig deeper.

Indunil Sikurajapathi: Explore more literature around your research topic. Find out if your research question has been answered before. You might need to refine or narrow down your research question. If you also teach, have a clear schedule for your research, and plan considerable time for your research. Learn how not to say 'YES' to everything. Learn when to say 'No'. Be Assertive! Feeling 'overwhelmed' is not a negative sign. It means your mind is caring about what you are doing!

Kristian Skytt Nilsson: Focus on the goal and sort the data. Smooth sea never made a skilled sailor.

Johannes Strobel: Howard Thurman: "*Don't ask what the world needs. Ask yourself what makes you come alive, and then go do it. Because what the world needs is people who have come alive*." I get reminded that this is a field and research area where different fields meet. My standpoint(s) of origin are important. Coming from education and going to engineering is different than the other way around… Life experience, phenomena, beliefs I bring, worldviews... all impact. Being aware of where I stand is important to expand.

Roland Tormey: Writing for diverse audiences is important in Engineering Education Research. Some readers are engineers, others are educationalists. Some do quantitative research, some do qualitative. Some do experimental research, some do cross-sectional research, and some do design-based research. They have different prior knowledge and different assumptions. You need to write in a way which communicates to all of them… Writing is a skill that needs to be developed (...and you never stop learning from feedback by reviewers, readers, etc.).

Esther Ventura-Medina: Wonderful to see so many young enthusiastic people. Taking ownership of the research is very important – being passionate and interested about your research work is key to success. It is similarly important to have a clear research question which can help you to define a methodology and data collection methods that can answer that question. Finally, some days are more difficult than others – research is always challenging in many different ways – do not despair and think of turning challenges into opportunities. Good luck to everyone!

3 REFLECTIONS AND WAY AHEAD

The SEFI 2020 Doctoral Symposium was successfully converted to an interactive online format. 21 doctoral students and 17 seniors worked together in forming the future of the engineering education research community. It will be an interesting dilemma whether to go back to the physical format, if and when it is possible again, or continue to develop the remote format. The most difficult alternative would be to arrange a hybrid format, with participants bot remotely and physically present.
The experiences from 2020 certainly showed that a remote format was feasible, but there are some trade-offs. One great advantage was that participants came from an impressive range from different countries, both seniors and doctoral students. Many of them would not have been able to travel to the conference. On the other hand, some participants found that a full day online was quite wearying, perhaps most so for those located outside Eurocentric time zones. For those who are travelling anyway, a day of face-to-face meeting is less tiring and may be even more rewarding. However, if the DS is not tied to the physical presence at the SEFI conference, other completely different formats are possible and could be discussed.
Finally, some advice was collected from participants in the SEFI Doctoral Symposium 2020 to a hypothetical person asking if they should attend next year:

- The field of Engineering Education is populated with researchers and practitioners with many different backgrounds. Each of them can teach you something useful, especially when you are not in the same field.
- I would encourage everyone to join the symposium and learn new things.
- Do it. Be very clear on what you want to gain from it.
- Attending the symposium will always have value even if it is only as a networking opportunity to meet new people and to share your own work. Beyond that you can take advantage of discussions with other students and more experienced researchers and perhaps pick up ideas and get feedback and support for your research work. It is always a winning formula :-)
- Definitely participate! You get to know so many people from your field, talking about your research feels very natural in the symposium and it is always good to talk to people outside your research group.
- Don't hesitate. It's a great opportunity to talk (passionately) about your PhD research with critical friends.
- Do it and prepare your main questions in advance
- If you have some things you are struggling with - which you probably do - and you want a new perspective on it, you should definitely join the symposium!

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The authors wish to thank every single participant in the Doctoral Symposium over the years, doctoral students as well as seniors, because the success of the activity is a direct result of your engagement and enthusiasm. We thank the organisers of the SEFI Annual Conferences for great hospitality during the pre-conference day. We thank SEFI for being entrusted with the stimulating task of organising this activity. Finally, we gratefully acknowledge how SEFI supports the EER field in many ways, among them the Doctoral Symposium.

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2020 SEFI FRANCESCO MAFFIOLI AWARD

USING A DESIGN STUDIO FRAMEWORK TO CREATE THE STRUCTURAL ENGINEERS OF THE FUTURE

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***Conference Key Areas**: SEFI Francesco Maffioli Award*
***Keywords:** Professional Skills, Design Studios, Future Skills*

ABSTRACT

Technological University Dublin (TU Dublin), are delighted to be named the winners of the 2020 SEFI Francesco Maffioli Award. We are a community of enthusiastic lecturers whose aim is to provide a student-centered approach to teaching which will equip our engineering graduates with the skills necessary to solve the challenges of our future.

Industry 4.0 will revolutionise the way we live, work and communicate with each other and engineers must develop appropriate professional skills and ways of thinking to meet the sustainability challenges associated with an ever-increasing, energy-consuming population.

In TU Dublin, we focus not only on the curriculum to be taught, nor on technical skills in isolation, but on a holistic education for our students. This paper highlights the use of Creative Design Studios in our structural engineering programme to develop and enhance both technical and professional skills in our engineering students, preparing them for life in engineering practice and in society as a whole.

Our mission: to produce industry ready graduates with the correct balance of skills to meet the needs of the profession and the challenges of the future.

1 BACKGROUND

Project Ireland 2040 commits €116 billion to an ambitious programme of infrastructure development works over the next ten years. This goal can only be achieved by engineers who are adequately skilled to work in an environment of accelerating change.

Engineers will certainly need fundamental technical skills, however professional skills and new ways of thinking are becoming increasingly important. Our findings from an Erasmus+ research project (www.astep2030.eu), on skills requirements to solve the SDGs (Figure 1) underpins the Design Studio Framework (Figure 2) described in this paper.

Fig. 1. Engineering Skills of the Future (A-STEP 2030)

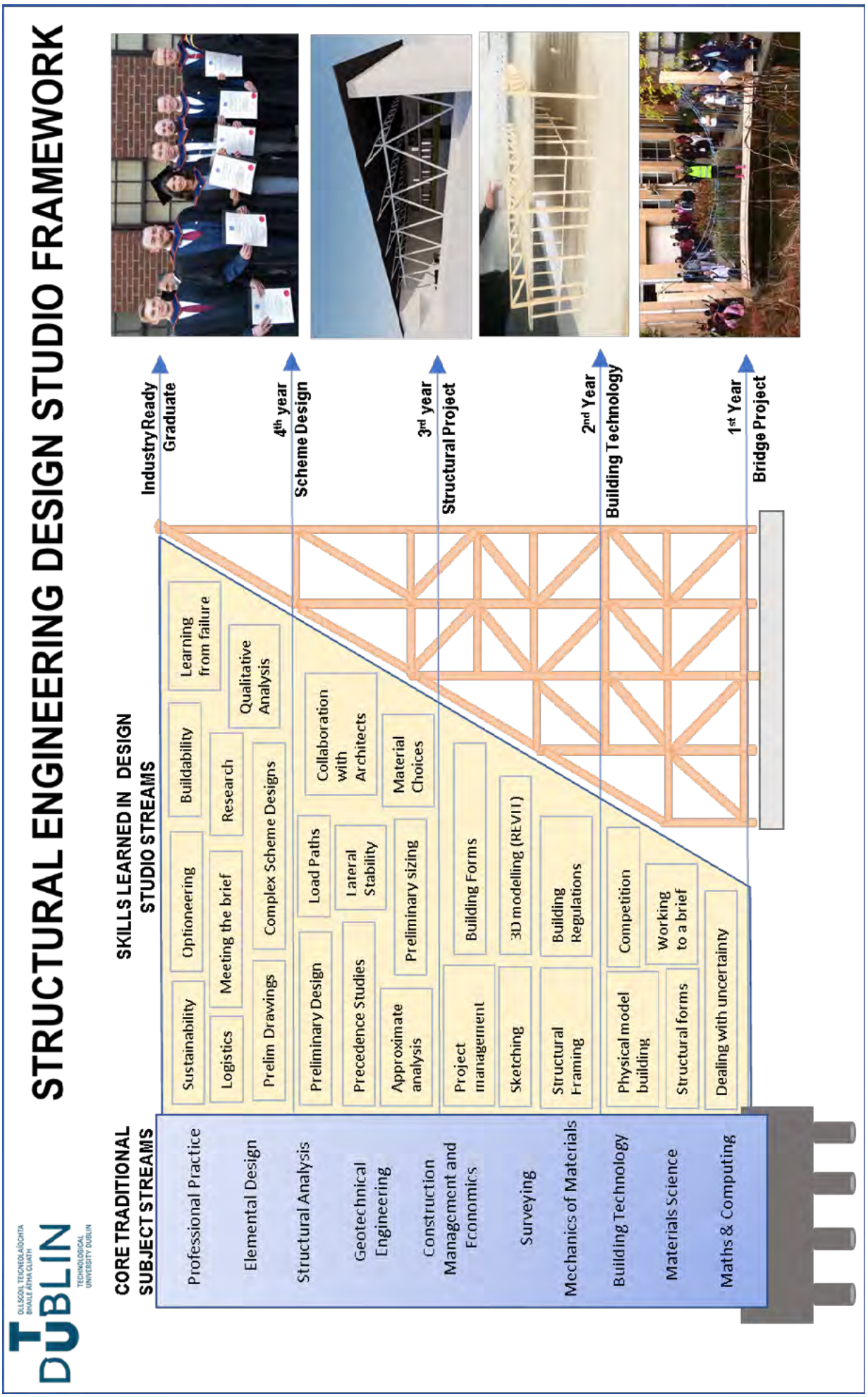


Fig. 1. Creative Design Studio Framework complementing core skills development at TU Dublin

2 INSPIRATION

Design Studios in each year complement a core built on strong foundations of technical knowledge. Students face complex and wicked problems and through scaffolding of their learning by academics with significant industry experience, they build upon previous knowledge and contextualise their learning. Our inspiration comes from Architectural Education and Problem Based Learning Approaches as follows:

Critiques and Design Studios have been used since the 1500s in architectural education [1]. Critiques require the student to engage deeply with design, consider alternatives and communicate with confidence to justify decisions, all of which parallels actual engineering practice.

Problem Based Learning (PBL) approaches encourage students to think critically to solve complex problems requiring creativity and higher order thinking in a groupwork setting. To become autonomous learners, they must be given opportunities to be creative, make mistakes, gain feedback and embrace uncertainty. Design Studios provide this opportunity.

We use our CREATE Education research group to gain feedback on pedagogical improvements within our courses (https://sites.google.com/a/dit.ie/create).

3 APPLIED TEACHING METHODS AND GROUNDS FOR CHOICE OF METHODS

Design studios are used to allow some 'creative space' within the curriculum whilst creating an authentic learning environment by using real life projects and scenarios. Here we briefly describe four modules which contribute to the framework.

3.1 First Year: Bridge Design Project

This PBL module presents an open-ended problem with social and environmental aspects. Students are given the problem: "Design and construct a pedestrian bridge for use in an emergency situation in a developing country". Students learn about structures, research, teamwork, project management, presenting, peer assessment and dealing with conflict. The project culminates in students building a full-scale bridge which is tested over the pond (Fig. 3). For an insight into students' experience see this video (https://tinyurl.com/y49ggtwu) @ 4 mins 20 secs.

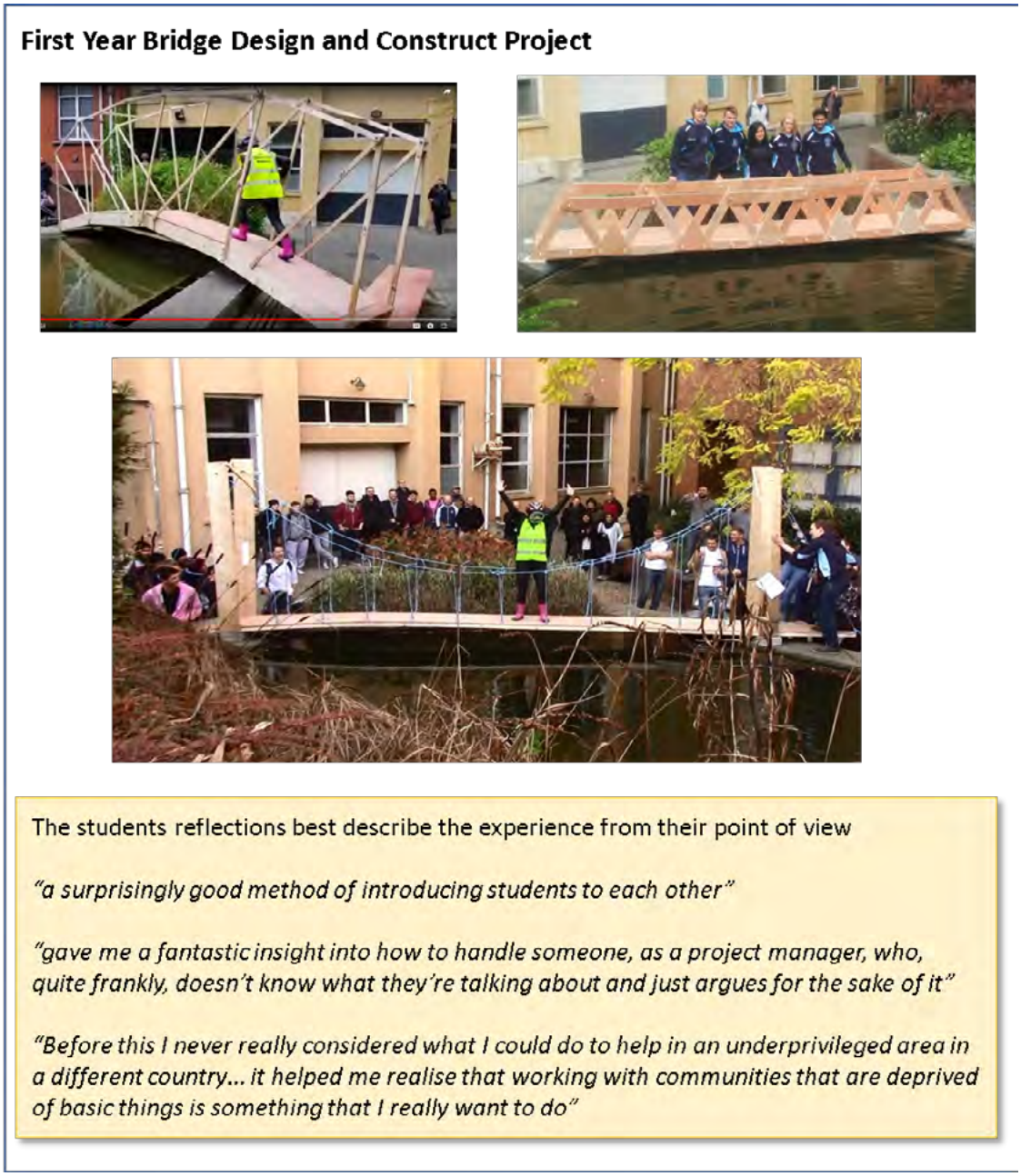


Fig.2. First year bridge designs and student reflections

3.2 Second Year: Building Technology

3D modelling is introduced as a tool in visualising designs and communicating design intent in the Design Studio in second year. Blended teaching approaches in this module cater to the diversity of the learner: learner needs, learning preferences and learner skill sets. Our lessons are guided by Universal Design for Learning, particularly in the use of Multiple Modalities to present the material e.g. video tutorials (Figure 4).

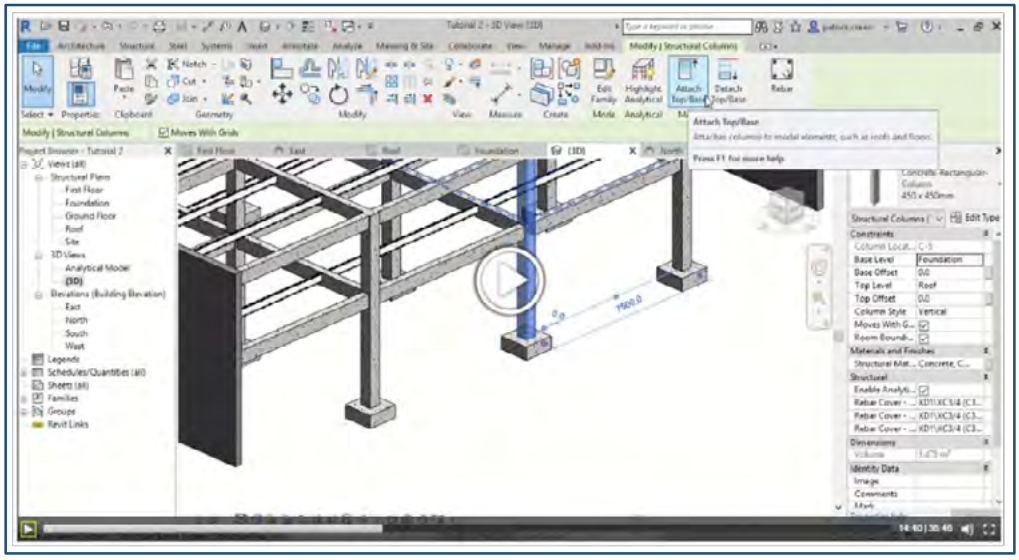


Fig. 3. Extensive use of video tutorials to enhance understanding

Most importantly however, we are impressed with the engagement and ability of our students to absorb, understand and produce outstanding work. Submissions (Figure 5) are reflective of the holistic nature of an engineer's work and the wide range of skills developed.

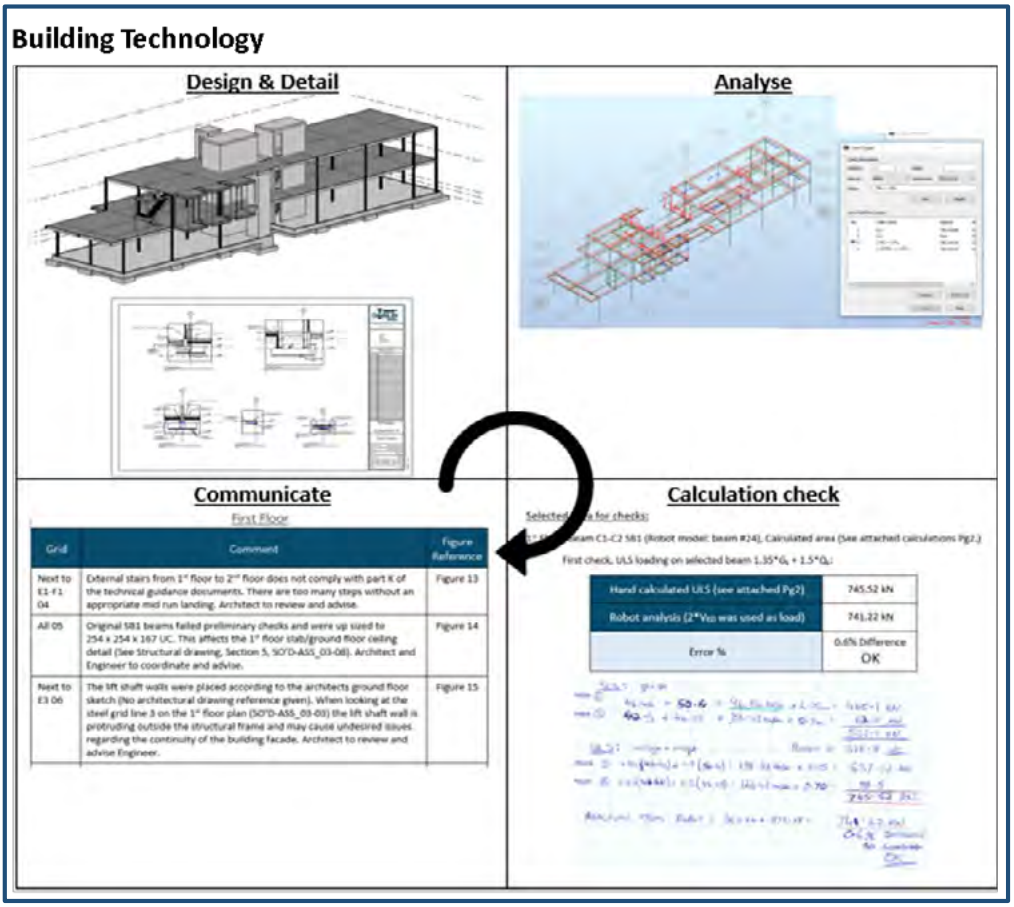
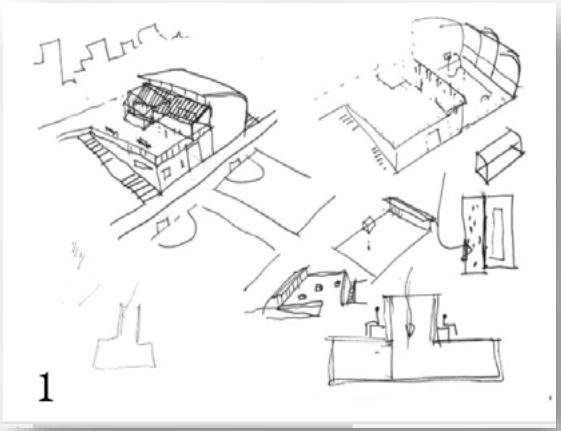


Figure 5: Typical student submission validating four aspects of learning: Designing, Analysing, Communicating, Self-checking and Validating

3.3 Third Year: Structural Design Project

This module focusses on interdisciplinary work, collaborating with architecture students. Students must develop multiple alternative solutions for building designs as a way of fostering creativity. The use of story boards and models with peer review and critiques provide ongoing feedback and enhanced understanding between disciplines. Application of engineering formulae to different structural forms develops quantitative reasoning skills.



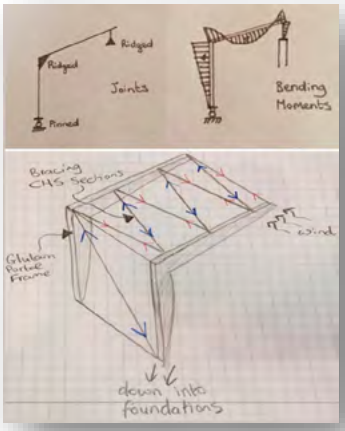


Figure 6a: Preliminary brainstorming sketches by students describing how the structure could meet the client brief

Figure 6b: 3D and physical models created by students helping them to visualise their proposed designs

Student Feedback
"The most important module. This is what we will be doing after college!"
"I enjoyed the practical side of work that will be done in a design office in future".
"It makes you think about real structures in real life"
"Helps understand and provide insights into the construction industry"
"Group work is closer to real world!"

Fig. 6: Structural Design Project student work

3.4 Fourth Year: Scheme Design

This studio is student centered, interactive and self-directed. Using a 'flipped classroom' students present precedence studies and scheme designs. Socratic questioning is used in round table discussions helping students to gain deeper understanding and appreciation of the topic. Collaborative projects with an engineering contractor develop the students' awareness of construction and site logistical issues on a real project to create an authentic learning environment as shown in Figure 7.

Fourth Year Scheme Design

Victor O'Shea, John Sisk and Son:

"We were very impressed with the standard of the projects that were presented for the Sisk Scheme Design. We were "blown away" by the professionalism of the presentations, the depth of knowledge that was portrayed and the time and effort that was inputted into each Scheme and in particular to the models.
We believe this module will embed the planning and technical requirements that are necessary for site work. It will also ensure that office based engineers will have an appreciation for site activities".

Student Feedback:

"I enjoyed the practicality of the module while still learning to apply our technical knowledge to structural engineering issues".

"Great preparation for beginning your career in a consultancy"

Figure 7: Scheme design site visit and feedback from SISK and students

4 RESULTS AND IMPACT

The effectiveness of the Design Studio framework is shown by the excellent standard of submissions (Figures 3, 5 and 6), and the high pass rate in these modules. The effect on students' professional skills in first year is highlighted by Beagon, Niall and Ní Fhloinn [2]. Feedback from our students (Figures 3 and 6), Industrial Advisory Board (Figure 7) and External Examiners (Figure 8) supports the Framework's impressive output:

External Examiner Feedback:

"a demanding test of creative design in the context of a realistic problem which will give the most able students the opportunity to demonstrate their strength"

External Examiner Prof. Roger Plank

Figure 8: External Examiner Feedback

5 SUMMARY

TU Dublin's School of Civil & Structural Engineering proposes the Design Studio framework as a way to build a curriculum to prepare students for work and life. We attest that the skills they develop in Design Studios align with those necessary to meet and achieve the complex challenges of our future.

Our methods are internationally applicable, aligning with SEFI's values of creativity, engagement and inclusiveness. Our next step is to undertake research into the students' experiences of the Design Studio Framework, including interviews with current students and recent graduates in preparation for submission in the European Journal of Engineering Education.

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